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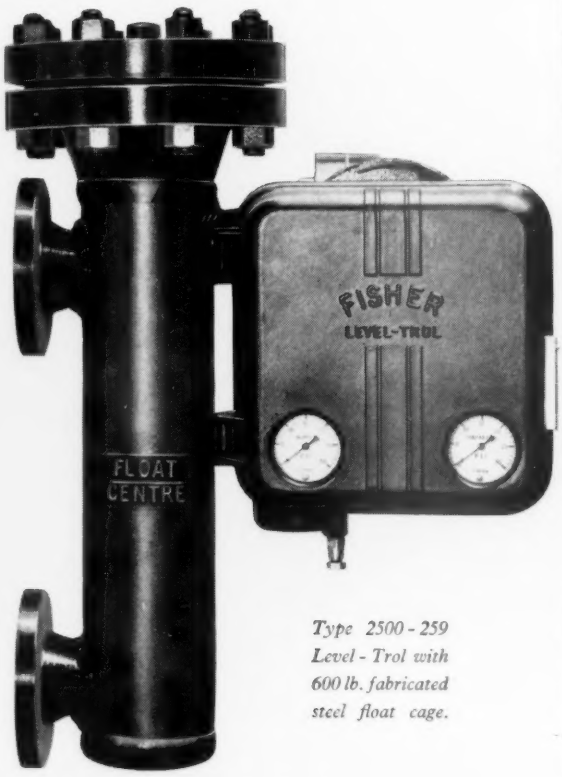


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# THE INSTITUTE OF PETROLEUM REVIEW

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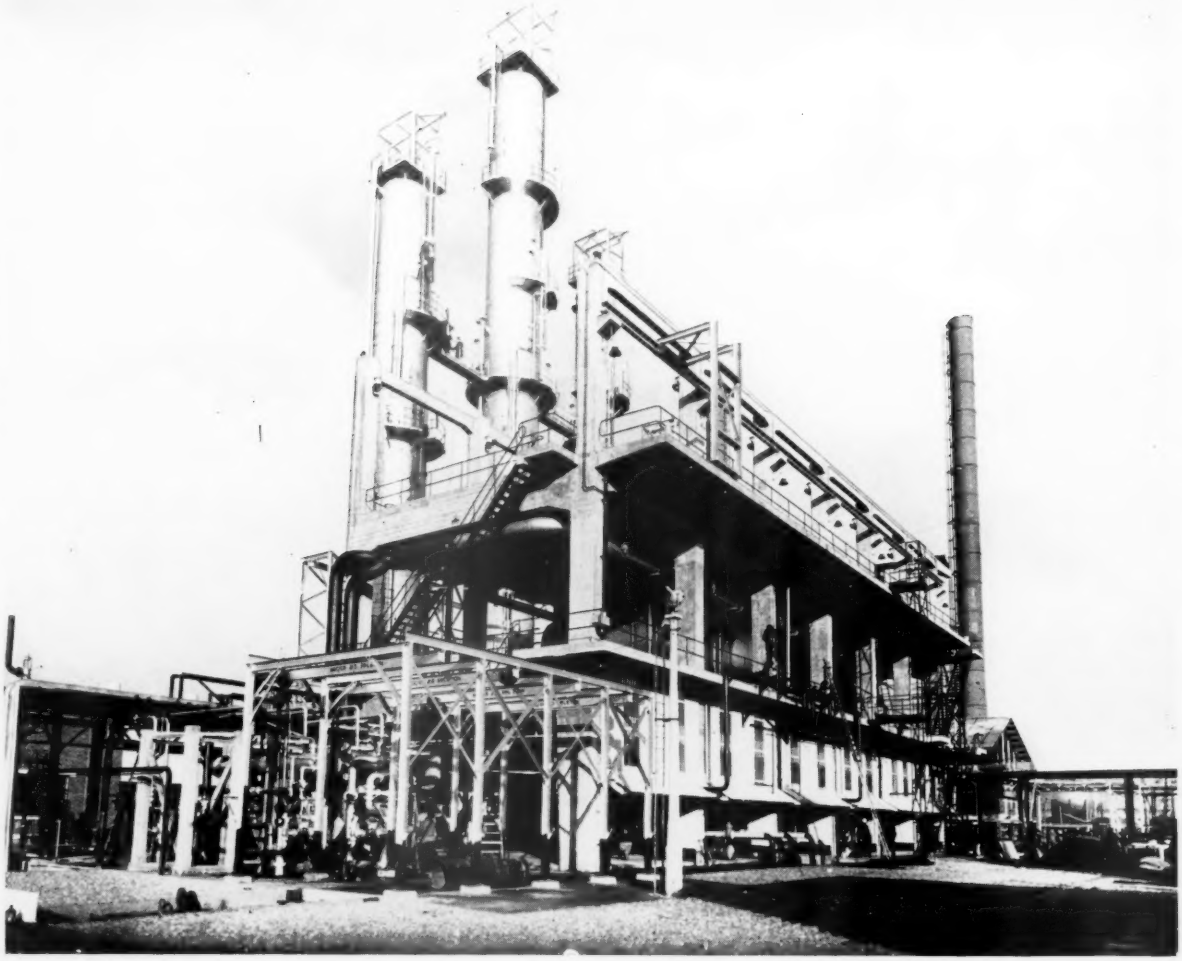

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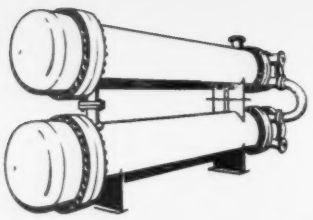

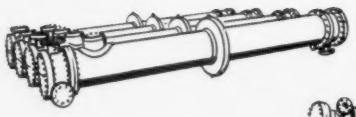

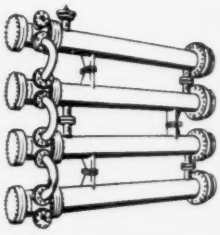

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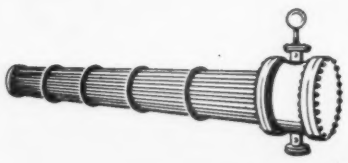

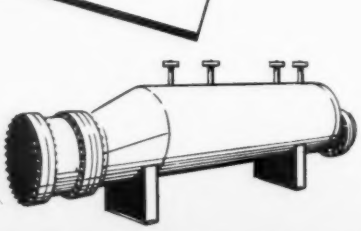

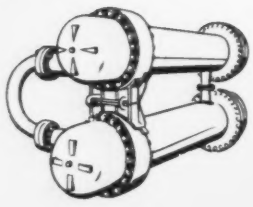

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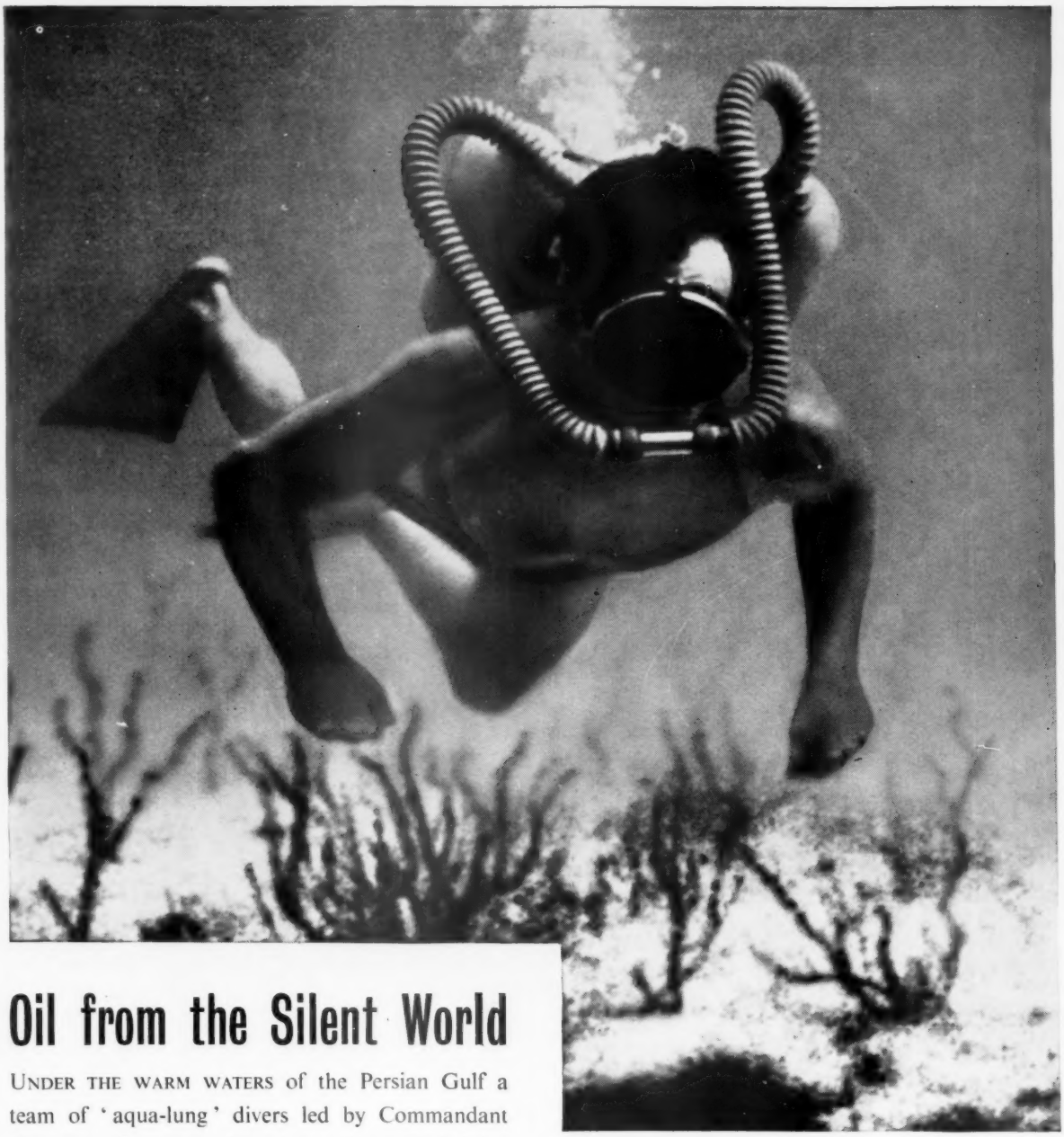

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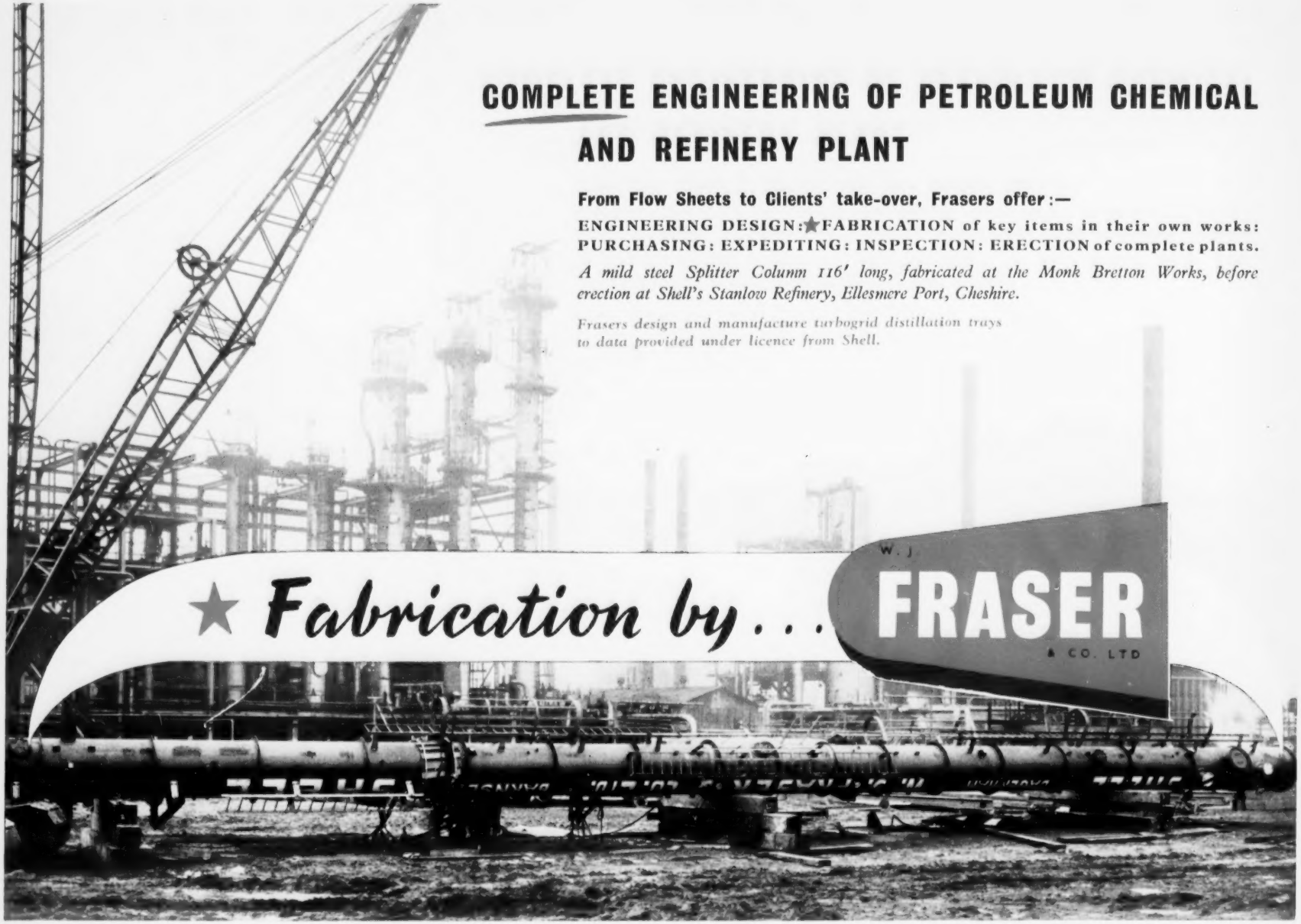
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# Additives for Petroleum Lubricants*

## A Review of Co-operative Efforts

*By* F. F. MUSGRAVE

### Introduction

"Alice Through the Looking Glass" contains the sentence "when I use a word it means exactly what I choose it to mean, neither more nor less" and in that sense, the word *additive* may be defined as follows: "A chemical or a group of chemical materials added to a petroleum product as a substantially minor portion of the whole, to enhance certain useful properties of a given petroleum fraction in service and/or to minimize or overcome certain defects and shortcomings which it would otherwise exhibit."

The term *petroleum lubricant* needs no separate definition since this may be considered, if desired, as simply an appropriate vehicle for additives. But perhaps that is going too far.

One of the keys to the successful use of additives lies in the principles of selection and it is always important and usually most difficult to enhance one property of a petroleum lubricant without affecting simultaneously other properties as well. It is of small value to roast the pig in the embers of the whole house and there are a number of examples of chemical or mechanical corrections being subsequently required in order to remove or minimize unwanted side-reactions or effects arising from the insufficiently considered use of additives.

### Practical Applications in Review

Approximately 25 years ago there began in the United States slow but spreading investigations to find ways to improve lubricant performance by adding special chemicals. Sulphur, graphite, chlorine, fatty oils, etc., were used in cutting operations, as rust preventatives, or to improve "oiliness," or "film-strength," that is, to give extra service properties of some sort. From the beginning the emphasis has continued to be on the performance qualities of lubricants which could be demonstrably improved with additives.

At present, the use of additives in lubricating oils has become so widespread and commonplace that the subject of a brilliant debate heard many years ago comes to mind: "Resolved that the practice of biography has increased, is increasing, and ought to be diminished." There have been suggestions lately that additives have been over-emphasized, but they have a substantial account to their credit and a glance at the record of practical improvements in lubrication would include contributions from the following familiar families of additives: pour point depressants; detergent-dispersants; viscosity index improvers; extreme pressure agents; film strength agents; anti-rust agents; oxidation inhibitors and anti-foam agents.

While useful members of the above groups have been developed chemically there has occurred over the same period of time a number of advances in the mechanical systems in which the various lubricants are used. Leaving aside all lubricants other than those for petrol or diesel-driven vehicles with their crankcase, transmission, and rear axle operating variables, it will be possible to find many examples of co-operative effort in the evolution of better lubricants in more efficient mechanical systems. This limited approach does not belittle the very considerable improvements in other fields of lubrication during the past quarter of a century, but helps to reduce the present discussion to a more manageable size. The principles by which chemist and engineer have solved common difficulties can be adequately illustrated without going over the entire field of lubrication in search of examples. The reduced target is still big enough to show that mutual respect for difficulties has stimulated corrective research when and where it has been most needed, whether on the chemical or the mechanical aspects of a given problem of operation.

### Mechanical Advances in Vehicle Design

Without attempting an expert assessment, it is obvious to all interested in engine and/or gear lubrication that remarkable engineering developments have been achieved since about 1925. A very short list would include the following: Bearing metallurgy; valve operation; hypoid gears; piston assembly; crankcase ventilation; fuel combustion; and automatic transmissions.

Taken together with many other separate refinements, these developments have led to greater power output per unit of weight, at higher speeds and temperatures and from more highly stressed parts. Fuel quality has improved radically so far as petrol is concerned, but the later advent of diesel fuels with higher sulphur-content has created special lubrication problems.

### The Practical Evolution of Additive Chemistry

The word *practical* is used at the head of this section because additive theory as such is scarcely at present a coherent body of thought. There are a number of hypotheses having limited value, and some rather fundamental work has been carried out on such matters as mechanism for preventing bearing corrosion and on so-called extreme-pressure lubricants. Nevertheless, the record so far shows many important practical benefits from using additives and few, if any, speculative generalities of more than passing significance.

A comparatively small group of chemical elements have found widespread use as additives and the well-worn favourites may be listed as: sulphur; chlorine; phosphorus; zinc; lead; calcium, and barium in various organic combinations. Other examples are: tin, chromium, and magnesium compounds, and fatty acid products. Although hundreds of thousands of chemicals have been brought down from the laboratory shelves for testing—or have been laboriously synthesized for possible use as lubricant additives—and although thousands of compounds and their homologues or allied structures have warranted, to the eye of faith, the taking out of letters patent—it remains true that very few survivors have gone on to perform in the commercial arena.

Some of the more important chemical groups in the present field of additives for crankcase oils are metallic sulphonates, phenate bodies, and dithio phosphates. It may be noted in passing that sulphonates have been extracted from lubricating fractions by strong acid in the course of refining processes for perhaps 70 years. About 15 years ago, however, they were first restored to lubricants, in suitable forms, to act as detergent dispersants. Thus "the same stone which the builders refused; is become — —" if not the head-stone, yet a principal part of the present additive structure. Similarly, phenolic compounds were used as inhibitors of oxidation rather than as detergents in the first instance, though they have since become useful in both directions when suitably arranged chemically.

Extreme-pressure additives rely mainly upon sulphur, chlorine, lead, and phosphorus compounds, with similar derivatives of fatty oils as occasional adjuncts. Not all of these may appear in the same lubricant, but there are three fairly well recognized types of combination: sulphur-chlorine-phosphorus, sulphur-chlorine-lead, and lead-sulphur. Of these, the first is in most general use

*Paper read to the Institute of Petroleum, Stanlow Branch, 17 November, 1953.

since the hypoid gear has come into increasing prominence.

It might appear, therefore, to be a relatively simple matter to select two or three chemical elements and make an effective additive combination by preparing suitably oil-soluble organic compounds in each case and then shaking or stirring the mixture, as prepared, into a lubricant. But this is far from true. A literally enormous background now exists of widespread and painstaking research and of extensive multiple testing—over years in some cases. A background such as this is essential before commercial manufacture can be successfully embarked upon. At the commercial stage also there now exists a highly specialized accumulation of chemical engineering techniques and novel processes which have been individually adapted to oil additive manufacture. All this has come about after great expense in time and money.

### Evaluation and Testing of Additives

In earlier days, a new compound could be tested for a short time in the laboratory or perhaps put straight into field tests in service conditions without elaborate precautions or misgivings in either case. Lubricants themselves were judged by a physico-chemical inspection routine which involved relatively simple and inexpensive testing procedures. The gravity, flash and fire points, colour, viscosity, cold test, and carbon or coke value were sufficient to characterize most oils.

The greater use of additives, however, has brought with it a growing desire to learn in advance how additive-treated lubricants may be expected to perform in service. Thus there has gradually come into being an increasingly complicated ritual of lubricant evaluation. Once he has produced a new additive compound or a novel additive combination, the chemist is now obliged to watch engineers, mechanics, and technicians putting it through a lengthy series of trials. These can take as long as two months for a single test in which intrinsic and extrinsic variables of every sort are brought to bear—sometimes involuntarily—upon the hopeful new additive. In the laboratory, the chemist can then survey the results of the mechanical test work and try to deduce a new and constructive approach from examination of the mechanical parts and oil samples after the test period. Meantime, the engineering branch seem to have done everything possible to discredit the potentially useful new creation by the exceptional severity of the chosen testing conditions.

It is admitted that this is the best way we now know in which to test a new additive-lubricant combination—simply to try it out. In the past a purely chemical approach by laboratory bench testing methods alone has been known to give quite the wrong answer as to how an additive-treated oil would perform in service. This is not to say that the chemist should give up. More rapid technical progress will be possible when reasonably sure means can be found of shortening the time and lessening the expense of additive-lubricant testing.

### Performance Tests

Present-day practice may be regarded as belonging to one or another of three kinds of performance testing: (1) Use of accepted, industry-wide, national or international standard conditions. (2) Use of secondary standards, which are less costly in time and/or money, in order to predict what the primary standard performance would be. (3) Use of exploratory performance testing which must be carried out where no recognized standards exist or where these are considered inadequate to assess properly the chemical research work accomplished or under way.

The first of the primary standards, as confined to vehicle lubricants only, consists of the well-known Caterpillar engine tests of about 500 hours each, in three separate lubricant quality levels and in three separate viscosity grades. Tnen there are the Chevrolet 6-cylinder-engine test (which consumes a large quantity of petrol during its high-speed 36-hour run) and the gear-lubricant tests on full-scale axles under high-speed conditions in one case and under high-torque conditions in another, as called for by the MIL-L-2105 specification in the United States. Over the past ten years, however, it is only fair to state that three other primary standard test procedures have been dropped—one of 500 hours, one of 250 hours, and one of 120 hours, which usually had to be run two or three times or more, before obtaining conclusive results.

In addition, Naval authorities hold their own views on standard tests in the United States. Finally, the introduction there of automatic transmission fluids in recent years has brought a new crop of standardized procedures to the fore under remarkably severe conditions which place both lubricant and full-scale equipment under extreme and prolonged stress.

### Secondary Standards

The secondary standards are often the result of the need to find a way to distinguish between potentially good—or bad—additives or base oils, or combinations, more quickly and more cheaply than the primary standards will permit. There must be a great many engines and procedures which are favoured in different laboratories for various purposes. Well-known smaller engine names are Lauson, Petter, Buda, J.A.P., Sunbury, New Lauson, and so on. The degree of correlation between any of these and one or more of the primary standards is a matter of experience which must vary widely from a finding of "quite satisfactory" to ultimate rejection of the secondary unit in question. Some years ago, one mechanical testing laboratory had a number of small units of one kind, all operating as filters for possible additive oil combinations, but it was never recommended to visitors that they should invest at once in one or two similar units for their own use. The experience that had come from careful observation and use of the test unit in question over the years could not easily be passed on and the real value, therefore, came from a painfully acquired knowledge of how to interpret results from that particular engine.

Exploratory performance testing, of course, may cover an area stretching forever in all directions if the dictum: "Nothing can be done without something being learned," is followed without limit. Yet testing of this kind is an essential and highly significant part of the research and development associated with additive-treated oils.

An example will show what can be involved in the work of one laboratory trying to correlate a Lauson engine procedure with results from the primary standard Chevrolet test: "Using an 80-hour test procedure, with bearing weights taken at 20-hour intervals, comparisons were made with a 72-hour Chevrolet test in regard to bearing weights and piston cleanliness. On the basis of approximately 75 engine tests, a basic correlation was evident between piston cleanliness of the two engines, and good correlation in regard to bearing weight losses was obtained in 80 per cent of the cases." Thus, after 11,000 engine-test hours a promising lead has resulted, but not a finalized technique.

Another example of extensive exploratory performance testing can well be selected from work to develop improved extreme-pressure gear-lubricant additives. An interim laboratory report states the following in summary: "During the last few years, the increases in engine outputs, resulting in higher unit loads and rubbing speeds on rear axle gears, are sure to result in increased demands on the lubricant. Consequently, an active programme is now under way with the object of increasing the high speed performance of gear lubricant concentrates without detracting from satisfactory truck or high torque operation."

"In a programme such as this, the old test procedures are bound to become inadequate and new methods for evaluation must be developed. One new test which is now being used for this purpose is a modification of a high-speed proving ground test as used by the Buick Division of General Motors. Our laboratory has adopted the chassis dynamometer for this purpose. At the same time, promising samples are tested on truck axles using several procedures in order that materials having improved high-speed performance will not be deficient under low-speed, high-torque conditions."

"We are also conducting field tests using four passenger cars and six trucks in order to confirm the information obtained in the laboratory."

Here are four simultaneous full-scale programmes being carried on in an attempt to improve general-purpose extreme-pressure additives. The sought-for product will not be found in a matter of weeks, and a year or more can easily be spent in this kind of research testing. It is an expensive and cumbersome method, but the many variables are such that no sure short cuts are known.

### Future Testing Procedures

For the future, or at least for the next few years, it is probable that performance testing of additive lubricants will continue to be related to familiar and to new, primary standards. An example of the latter has already appeared in the combination of procedures laid down for automatic transmission fluids. Three separate engine procedures must be satisfactorily completed in order to obtain full qualification of a new additive-treated fluid and there are a number of separate bench tests as well.

The Caterpillar engine shows no sign of being displaced in its field as an internationally accepted primary standard, but the L-4 procedure, using the Chevrolet, is expected to be replaced in the near future in the United States with a new oxidation test engine. Twenty-five of these units are now being built to a co-operative design approved by the Co-ordinating Research Council. The Council includes members from both the automotive and petroleum industries. Perhaps the time will come when this new engine in turn can be replaced by an oxidation test (or tests) for primary standard purposes based upon the results as obtained by chemical laboratory, or bench, techniques. If results of at least comparable usefulness could be achieved by these means, there would be a considerable saving in time and expense.

Exploratory performance testing is bound to expand and extend in many forms as efforts are made to tailor the individual chemical-oil combination to specific types of service conditions. The law of diminishing returns must, however, eventually limit this type of investigation. Thus we shall probably never see a packaged additive which must be separately injected into the third, fifth, and eleventh cylinders of some Minerva Super Sixteen of the future so as to obtain maximum performance.

As the fundamentals underlying so many lubrication problems become better understood and when families of chemical additives have been assessed more specifically as to their individual properties and propensities, it may be feasible to carry out neatly and precisely in a few weeks the evaluation and testing of an additive for a new service application which can take years in the present state of knowledge. That time seems far off, however, and it is unlikely that extensive full-scale performance testing will ever be considered unnecessary. A balance will emerge between selection by rapid and accurate prediction methods and the slow accumulation of trial and error results based on inspired empiricism and interpreted by statistical analysis.

### Progress from Chemico-engineering Co-operation

In the interaction of additive-treated oils with various mechanical units there have been some outstanding examples of co-operation in the mechanical and the chemical aspects of individual problems during the last 15 years. In considering some of these in more detail, it is evident in retrospect that a given problem has been brought part way towards solution by engineering development, then helped on its way by chemical developments—or *vice versa.*

### Effect on Bearing Surfaces

For example, when cadmium-silver bearing metal surfaces were introduced, they had certain manifest operating advantages over the earlier soft metal bearings and then copper-lead bearings were later introduced. They could also carry higher unit loads and could safely operate at higher temperatures. The oils in use at that time, however (about 1936), caused rapid corrosion under prolonged high-speed and high-temperature operating conditions. The eventual introduction as additives of suitable oxidation inhibitors and of materials which allowed the formation of a protective coating on the bearing surfaces then stabilized the position and the use of copper-lead bearings has since become commonplace.

Then, with higher unit loads on bearings, there came higher power output engines with increased crankcase temperatures and more rapid oil deterioration. The use of so-called "detergents" in combination with the oxidation-corrosion inhibitors gave rise to the original "Heavy Duty Oil" concept which is now so familiar. At one period, however, detergent-containing oils were used in one class of engine which would have rapidly corroded the bearings of other makes. Some of these other makes were, in turn protected by inhibited but non-detergent oils. Suitable combinations were evolved but a great deal of co-operative testing and mutual reviewing of problems and progress took place between petroleum-minded engine builders and mechanically-minded petroleum chemists before the first, generally useful, heavy duty specification was put into practice.

In that connexion, there was a paper presented before a joint automotive-petroleum meeting in the United States with the somewhat blunt title: "An oil man looks at dumb engineering," or words to that effect. It was a general lament over shortcomings in American engine design which hampered or frustrated the petroleum chemists' attempts to produce oils which would give better satisfaction in service. The paper stressed that a sump construction allowing only 80 to 85 per cent of the old oil to be drained put a new oil charge under a grave handicap at once. Crankcase ventilation was said to be inadequately catered for, and diesels were broadly criticized as being too particular as to their fuel requirements. This good-natured yet serious broadside did not revolutionize engine design overnight, but it probably helped to accelerate many of the mechanical developments which were already under way. Certainly great progress has since been made in crankcase design, valve design and operation, ventilation and thermostatic controls, in diesel fuel quality tolerance, and so on through many other items which affect the ability of a given crankcase oil to give the best possible service results.

Referring to the so-called hard metal bearings, it has more recently been noticed that certain bearing alloys of phosphorus with bronze did not withstand prolonged high-temperature operation in the presence of certain broadly acceptable types of additive-treated oils. Here is a case where alternative bearing metal compositions were tested, approved, and adopted by the manufacturers, and complaints of high temperature corrosion from that cause have now largely disappeared. Simultaneously, it should be said that chemical improvements were also made in the additive family concerned, which made the treated oils less liable to cause phosphor-bronze bearing corrosion at high temperatures. Both engineering and chemical experiments, therefore, have contributed to solving these difficulties.

### Hypoid Gear Lubrication

Another problem of surfaces and surface effects that has caused great expenditure of time and effort is that of hypoid gear lubrication. Extreme-pressure, gear-lubricant additives were in existence before the first highly stressed hypoid assemblies were used. In recent years, however, with greatly increased horsepower being transmitted through heavily overloaded units, increasing demands have been made on the lubricant and its additives. It is particularly true of new hypoid gear sets that their lubrication requirements are initially very severe indeed and recent experience has demonstrated the value of pre-coating the gears with a thin phosphate film. By this relatively inexpensive procedure a hypoid gear lubricant, satisfactory for break-in and running on a given-sized engine and non-coated gear combination, can be quite safely used with an engine of greatly

increased power, transmitting through the same-sized gear set. Processes of this type for pre-coating hypoid gears have been very successfully used in both the U.S.A. and the U.K.

### Diesel Engines

Finally, the tremendous increase in the use of diesel engines over the past ten years has given rise to problems of fuel supply and quality, and the demands made upon supplies have led to an increasing use of fuels of higher sulphur content. This is all fairly recent history and the sequence of events may be recalled as having been somewhat as follows: As higher-sulphur-content fuels came into more general use, it became more difficult in certain diesel engines to maintain engine cleanliness and reasonably low rates of piston ring and cylinder bore wear with the then established grades of H.D. oils. It was not possible to use low-sulphur fuels exclusively on a world wide basis, and the oil companies and additive manufacturers were therefore asked either to take the extra sulphur out of the fuels or to use additives —presumably either in the fuels or the oils—which would restore desired standards of performance. At the same time, potentially efficient new diesel units, supercharged to a relatively high output, had been introduced by the engine maker who publicized these difficulties. These newer units gave the most trouble, but an initial solution to the problem was provided by additives used in the oils in greater percentages than ever before. As in the past, a primary standard engine test was established and concentrated investigations were made. After five hundred hours on the supercharged single-cylinder diesel, using one per cent sulphur-containing fuel, good results could be obtained with oils containing up to about twenty per cent of additive. These Series II or Supplement II oils have been in general use about four years.

More recent research by the petroleum chemists has led to a gradual attack, at the refinery stage, on the sulphur content of distillate diesel fuels, and the overall average sulphur content of diesel fuels in the United Kingdom which was approximately 0·75 per cent a year or more ago, is tending to fall rather than to rise. This is not universally true, however. It is probably unfair, moreover, to make a simple generalization equating sulphur percentage in a distillate diesel fuel with its tendency to increase engine deposits and rates of wear. The source of the original crude is undoubtedly another factor, since different sulphur compounds are likely to occur in similar fuel fractions from different crude sources. It has been said, for example, that certain Western American fuels cause more difficulty than some Middle East fuels.

Together with sulphur reduction in the fuel, additive chemistry has also progressed recently and the primary-standard, supercharged-engine test with one per cent sulphur-containing fuel can now be passed successfully with oils containing not nearly twenty per cent of additive but about six and a half per cent of additive.

### Present Benefits from Past Efforts

It is possible now to see how the use of additives has promoted the better functioning of better oils in better mechanical equipment. For example, the more highly stressed high compression petrol engines, of much greater efficiency than was possible 25 years ago, are benefiting from the use of additive-treated oils. One of the world's largest motor groups is, in fact, recommending that its principal petrol engines be operated on heavy duty oils with an additive content which was once considered desirable only for certain types of diesel engines. Similarly, the severely loaded hypoid gears now coming into more general world-wide use cannot run on purely mineral oils, and recent research on additives has had to meet progressively more stringent performance requirements in this extreme-pressure field. Diesel engines themselves have become more efficient, more heavily loaded in many types of service, and better able to deal with fuels of varying quality—due in part to growing awareness of the value of additive-treated oils.

### Long-service Lubricants

One by-product of this process of developing higher quality levels of lubricants containing additives, is that it has been possible in many cases to lengthen appreciably the service life of a given lubricant charge. This has been true of turbine and transformer oils, and it is also common practice nowadays to use crankcase, transmission, and rear axle oils for longer periods than would formerly have been considered practical. Thus, many rear axles may now be drained and refilled at two or three, or many times the average mileage accomplished between oil changes twenty-five years ago, and crankcase oil changes have been pushed up to many thousands of miles in well-regulated commercial fleets of vehicles. This is not to say that the extra cost of a relatively highly additive-treated oil should be automatically absorbed by a correspondingly longer drain period. The more expensive oils are too often dealt with that way through a short-sighted attitude towards first costs. Oils are cheap in relation to overall vehicle-operating costs and in use they should be regarded as one means of insuring against premature internal mechanical deterioration of the equipment. Viewed in this light, a more expensive oil can repay its cost many times over during the life of a given vehicle if the drain periods are not unduly prolonged.

Higher performance standards are, therefore, possible at present from more efficient mechanical units which are lubricated with oils having the advantages of the past years of progress in both petroleum and additive research. This trend towards higher efficiency and better quality is now generally recognized and the engine manufacturers have been able to plan for its continuance by designing equipment which places ever greater demands upon the lubricants to be used. The most advanced types of internal combustion engine, whether for land or sea use, are based today upon the use of additive-treated oils as a matter of course. High-speed railroad diesels now in general use in the U.S.A. and the new, triangular marine engine whose design was recently publicized here, are two examples of designs whose lubrication requirements cannot be fully met by straight mineral oils.

### Possible Future Developments

One example can be mentioned again here, that of automatic automotive transmissions, which represent a recent minor revolution in the United States. These units are gradually being introduced elsewhere as well. Not only do their lubrication requirements include a detailed series of properties which rely upon chemical additives, but the treated lubricant is also considered as a semi-permanent part of the transmission unit and is used for 25,000 miles or more between change periods. It may be remarked again that the approval testing requires three full-scale engine test procedures, which represent only a portion of the full programme for the acceptance of a new automatic transmission fluid.

Turning to diesels again, it is probable that there will be an increasing use of lower grade and residual fuels, some of which present very serious sulphur and ash problems. Additives now known are often helpful in mitigating the wear and corrosion to which very low grade fuels give rise, but this is only a partial answer. Further improvement may come about through a combination of developments in refining, in additives, and in mechanical design.

Jet engines, up to the present, have presented their own lubrication problems and specialized synthetic chemicals, without admixture of petroleum oils as such, seem to be finding a place. It would be rash to speculate any farther than to say that these synthetics may well be made from petroleum-based raw materials.

A certain amount of highly specialized work has also been done recently with solid lubricants, such as molybdenum disulphide, which have certain desirable properties and some limitations. There are also the new, polymer, bearing surfaces with interesting properties and these may be harnessed to lubrication applications

on a large commercial scale at some future time. A prominent scientist in the United States described some years ago the outstanding merits of volatile organic halogen compounds as lubricants—but their general commercial use is still awaited.

In the field of rust and corrosion prevention, the study of all that is implied by the physics and chemistry of surface action continues to produce more efficient applications of specific chemical mixtures in petroleum vehicles. It has been suggested, for example, that considerably more attention must be paid in the future to the rust-proofing and general anti-corrosion qualities of the ordinary heavy-duty-style crankcase oils. Here again it may be remarked that currently used methods of testing leave something to be desired. It is very difficult, for example, to correlate long-term metal corrosion storage results from humidity cabinets in different laboratories.

### Co-operation for Progress

In the past it has been sometimes said that the designers of equipment in the United States have had an undue influence on the quality of the lubricants which their units could or should use. Whether or not this is fair comment, it is unlikely that engine builders and lubricant producers would now be providing jointly the high standards of equipment performance exhibited very generally in most parts of the world if each had paid no attention to the needs and limitations imposed by the field of the other. On balance, both petroleum chemists and engine designers and builders have gained a great deal by close study of one another's problems. The improvements, plain to see, in both engines and oils are the best evidence that cross-studying and co-operation have benefited both groups—and the customer.

There is room for more active co-operation, and the additive manufacturer, who is in some senses an intermediary, must obviously be ready to work with both parties for the final benefit of the ultimate user. He should be able to look forward to the benefits from ever better-designed engines using more and more suitable oils, which may be fortified with ever more carefully tailor-made additives. Additives have amply justified the efforts spent in their development up to the present and the newer and better products of the future will be brought to light more quickly through a co-operative approach to common problems by all of the principal parties concerned.

### Discussion

**J. C. Cragg:** When additives were in their infancy about 20 years ago, there seemed to be two approaches to their use: they could either be employed to make a good oil better or to make an oil of medium quality equal to the best non-additive oil. The former view has, of course, now prevailed. An early example of the use of additives, which had an obviously good effect, was the addition of an oxidation inhibitor to the high V.I. "Penna," type of turbine oil, which previously often tended to rapid high acidity development in use.

With regard to the assessment of additives, there seem to me to be a few types of additives which can be evaluated in the laboratory, in particular, pour depressants and viscosity-index improvers. With both of these the effect on the oil can be measured by a recognized laboratory test.

**Dr Musgrave:** I agree with Mr Cragg that the correct use of an additive is to improve the behaviour of an otherwise good oil and not to mask the deficiencies of an inferior oil; in any case, in comparison with the present high cost of additives the difference in cost between a good and an inferior base oil is relatively small, and the use of the latter would be uneconomic.

In reply to Mr Cragg's point regarding laboratory evaluation of certain additives, I cannot entirely agree. May I remind him of the phenomenon of pour reversion in the case of oils with pour depressants incorporated therein and of the effect of high rates of shear on oils doped with V.I. improvers? In both these cases assessments based purely on laboratory tests could lead to misleading indications.

**C. D. Brewer:** Whilst I agree with the speaker's plea for increased collaboration between the engine manufacturer and the oil industry, it should be borne in mind that conditions in the U.K. are, in this respect, somewhat different from those in the U.S.A. In the former country the export market is of far greater importance than in the latter and, when catering for the export market, a design of rugged simplicity, which will work when supplied with inferior fuels and lubricants, is a primary requirement.

**Dr Musgrave:** I agree, but, even in the export field, I think rugged simplicity will eventually have to yield to more elaborate designs in which higher quality lubricants, and fuels, will have to be employed.

**A. Cluer:** Would Dr Musgrave give his opinion on the suitability of various sulphonates for additive preparation. Two theories appear to exist regarding the criterion for oil-solubility as against water-solubility. On the one hand, it is said that a mol. wt. in excess of 420 indicates preferential solubility in oil as against water, whilst the other view is that water-solubility is conferred by the presence of two sulphonate groups in the molecule. Another point in connexion with sulphonates is the differing specifications which are given by different users who are making the same product, namely calcium and barium sulphonates. In one case we have a preference for a rather narrow molecular weight range, 450-480; in the other, a minimum mol. wt. of 450 is required, with no upper limit. What is the significance of molecular weight in the preparation of calcium and barium sulphonates?

**Dr Musgrave:** The theoretical bases for the additive manufacturers' requirements are but slightly understood. The empirical basis of past experience is the safest guide. In any case the mol. wt. of a sulphonate is only one, and not necessarily the most important, of its characteristics.

**Mr Seiflow:** What value, if any, does Dr Musgrave attach to laboratory tests in 4-ball and similar machines, as a substitute for larger scale trials.

**Dr Musgrave:** Very little indeed. Extensive work has shown that whilst an individual laboratory test machine, *e.g.*, the 4-ball, may give reasonably concordant results on its own, such results bear no relation to those given either by other machines of a similar type or by full-scale (*i.e.*, axle) trials; there is thus at present no substitute for the latter.

**V. Biske:** Dr Musgrave has stated that the general effect of additives in lubricants is to extend the lubricant change period in automobiles. In some instruction manuals the importance of frequent changes (as often as every 5000 miles) is stressed for axles in which extreme-pressure oils are recommended.

**Dr Musgrave:** Recent work has altered previous views on this point. There is evidence that the use of an extreme-pressure lubricant conditions the working surfaces, and that axle oil changes can be at intervals of 20,000 miles or more.

**J. S. Parker:** I discussed the question of the mol. wt. of sulphonates recently in the U.S.A. and the view was expressed that in the mol. wt. range 430-470 there were unlikely to be any water-soluble sulphonates present. It must be remembered that the mol. wt. ranges which are asked for are those which correspond to by-products from white oil manufacture and which have been found, as Dr Musgrave has said, to work in practice.

The high content of additive in some oils which has been mentioned by the lecturer must be rather a surprise to some of us. In connexion with inhibitor additives, the possibility of increasing the oxidation resistance of petroleum fractions by the replacement of a selected fraction of the material which has been removed during refining should be considered.

**Dr Musgrave:** As regards high additive contents, whilst it is true that a few years ago the oils known as "Supplement II" were carrying additive concentrations of as much as 20 per cent, this phase is now passing and such oils may now contain about 6½ per cent of additive. It is nevertheless true to say, in general, that additive contents of oils are steadily increasing.

# The Eastlake Medal of the Institute of Petroleum

## FIRST AWARD TO G. H. COXON

In 1953 the Council of the Institute decided to inaugurate a new award "for long and meritorious service to the Institute". For the purposes of the award the period of service was to be not less than ten years and only one award should be made in any one year unless the Council decided that some special circumstance warranted more than one award.

It was decided that the award should take the form of a medal to be known as the "Eastlake Medal" in recognition of the work which the late Mr Arthur W. Eastlake did in connexion with the formation and building up of the Institute.

It will be recalled that Arthur W. Eastlake was the co-founder with the late Sir Boverton Redwood of the Institution of Petroleum Technologists, the original name of the Institute, in 1913. He was also its Honorary Secretary from 1915 to 1948.

It is fitting that the first recipient of the Eastlake Medal should be George H. Coxon, the Honorary Treasurer of the Institute. Since 1936, when Mr Coxon was first elected to the Council, he has continuously served the Institute in some position. Most notable has been his work in regard to the finances of the Institute—he joined the Finance Committee in 1936, was its chairman from 1940 to 1947, and since 1946 has been the Honorary Treasurer. Mr Coxon has also served on various other Committees of Council—Election, House, Public Relations, and Publications and acted as Chairman of the Council during the Session 1946-47.

The presentation of the Eastlake Medal to Mr George H. Coxon was part of the proceedings of the 41st Annual General Meeting of the Institute on 21 April 1954. Unfortunately, on account of ill-health, Mr Coxon was unable to be present to receive personally the Medal from the hands of the President. However, the suggestion was made by the President that a delegation of Council should visit Mr Coxon as soon as circumstances permitted and take the Medal to him.

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# T. Dewhurst receives the Honorary Fellowship

*At the AGM of the Institute of Petroleum on 21 April Mr T. Dewhurst, Past-President, was presented with the Honorary Fellowship of the Institute. Here he is seen being congratulated by the President, signing the book of honour, and at the Council Dinner when he entertained those present with some interesting and amusing memories.*

# The IP Council and Officers 1954-55

At the Annual General Meeting of the Institute on 21 April 1954, the nomination of Lt-Col S. J. M. Auld, O.B.E., M.C., D.Sc., as President for the Session 1954-55 was unanimously approved.

Colonel Auld, who has previously served as President during the period 1937-39, was first elected to the Council in 1932 and became a Vice-President in 1935. He is at present chairman of the House Committee, and a member of the Finance, Research, and Standardization Committees. During his membership of the Council he has also served on the Awards, Election, Engineering, and Publications Committees and has been of considerable assistance to the Institute in many ways.

Joining the Anglo-Persian (now Anglo-Iranian) Oil Company in 1919, Colonel Auld spent nine years on field and refinery work in Persia and in Burma. He spent the next eighteen years in executive appointments with the Vacuum Oil Company Ltd., and with the Socony-Vacuum Oil Company Inc. until, in 1946, he retired from the appointment of Chief Technologist to Vacuum. Since that time he has acted as a consultant and as a director of American Locomotive Export Company Inc., and other concerns.

First commissioned on the Unattached List in 1909, Colonel Auld served with particular distinction in both wars. In the 1914-18 war he served with the Royal Berkshire Regiment and later with the Royal Engineers. He became Chemical Adviser to the Third Army and commanded the British Gas Warfare Mission to the U.S.A., subsequently serving with the American Army in the Argonne and receiving the American Distinguished Service Medal.

In world war II he was adviser on flame projectors to the Petroleum Warfare Department and Technical Adviser to the Petroleum Board, jointly with G. H. Coxon, J. A. Oriel, and H. C. Tett. He was chairman of the Technical Committee of the Lubricating Oil Pool, the Technical Sub-Committee of the War Cabinet Committee, and the Enemy Oils and Fuels Committee.

Colonel Auld has contributed widely to the literature on petroleum, particularly on the subject of lubrication.

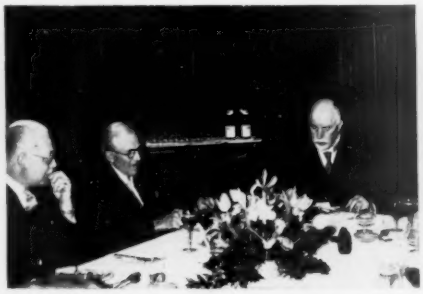
He is Hon. Treasurer of the World Petroleum Congress; Hon. Member of ASTM D2 Committee; Chairman of the Petroleum Industries Committee and Member of the General Council, BSI; a Governor of Sir John Cass's Foundation, and Past President of the Oil Industries Club.

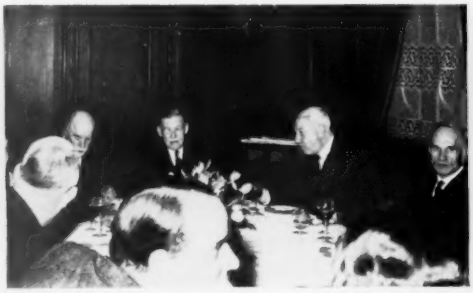
At the same meeting Professor Frank Morton, Ph.D., D.Sc., was without dissent elected a vice-president in place of Dr E. B. Evans who retired on completion of his 3-year term of office as a vice-president.

Frank Morton, who since 1949 has been a professor of chemical engineering at the University of Birmingham, has long been active in Institute affairs abroad and at home. For the period 1942 to 1945 he was honorary secretary and treasurer of the Trinidad Branch and, apart from his other activities, takes a keen interest in the Students' Section of the Institute which now forms a lively section of the Birmingham University Chemical Engineering Society.

First elected to the Council in 1947, Professor Morton previously served as a vice-president for the period 1950-53. At present he is chairman of the Research Committee and a member of Aviation Products Data, Benevolent Fund, Branches, Election, and Finance Committees, and has also served on the Education, Public Relations, Publications, and Standardization Committees.

After taking his degree in 1936 at Manchester University he became a research chemist in Trinidad with Trinidad Leaseholds Ltd. and in 1940 was appointed to be superintendent of research and development. This position he retained until in 1945 he was made chief chemist to the Company and returned to England. In December 1948 he resigned from Leaseholds and went to Birmingham University.





*Among those present at the Council Dinner following the AGM were* (left-hand photo): *A. C. Hartley, E. A. Evans, T. Dewhurst;* (centre photo) *T. Dewhurst, Col S. J. M. Auld, H. S. Gibson, A. T. Wilford, and in foreground, E. J. Sturgess;* (right-hand photo) *E. C. Masterson, J. S. Parker.*

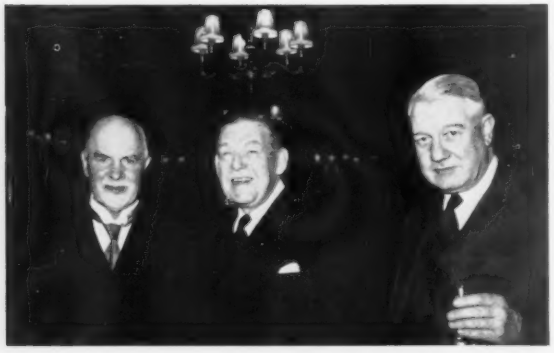
## COUNCIL

The five vacancies on the Council were all filled by the re-election of the five retiring members, there being no other nominations. The five re-elected members were: W. S. Ault, Dr E. B. Evans, D. L. Samuel, E. J. Sturgess, and O. F. Thompson.

As *ex-officio* Members of Council to represent the Branches, the following were nominated and elected unanimously: H. H. Ballard (*Northern*); S. A. Berridge (*Fawley*); W. H. Davies (*London*); N. W. Grey (*South Eastern*); E. J. Horley (*South Wales*), and W. M. Stirling (*Scottish*).

## HONORARY OFFICERS

G. H. Coxon (Anglo-Iranian Oil Co. Ltd.) was unanimously re-elected as Honorary Treasurer, and C. Chilvers (Esso Petroleum Co. Ltd.) as Honorary Secretary.



*The new President* (centre) *with* (left) *Mr T. Dewhurst* (Past-President) *and Mr H. S. Gibson, the retiring President. A picture taken at the Council Dinner following the AGM.*

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## COUNCIL COMMENTARY

Council met on 14 April under the Chairmanship of Dr E. B. Evans, Mr Gibson, the President, being unavoidably absent in Iraq. Discussions dealt with the activities of certain of the Council Committees, with reports on the progress of the Economics and Operations Group, and on the appeal for a permanent petroleum exhibition at the Science Museum.

The reports regarding the activities of the Branches show that these are in a very active and healthy condition and that they are fulfilling their purpose in a very satisfactory manner. The Branch representatives for 1954-5 were approved.

The Finance Committee presented the balance sheet for 1953 and Mr H. Hyams, its Chairman, explained the position of the Institute's finances in his usual lucid manner. These accounts are, of course, those to be presented at the 41st Annual General Meeting. Council were gratified to learn that the financial position of the Institute of Petroleum is sound and showed an improvement over 1952.

The activities of the Publications Committee were summarized by Dr E. B. Evans who observed that much attention had been given to the publication of the Abstracts to render them more suitable for current requirements. The position regarding papers for publication is quite satisfactory and it was anticipated that those to be presented at the Summer Meeting would be of very considerable interest and should also provoke a great deal of interest and discussion. It was agreed that the programmes of papers presented during the Session had been extremely interesting and of excellent quality.

The Chairmen of Council committees for 1954-55 were submitted and approved. Professor F. H. Garner unfortunately has found it necessary to relinquish the Honorary Editorship of the Journal and his Chairmanship of the Publications Committee. Council expressed their deep gratitude to Professor Garner, for his many years of publication and editorial work which had contributed in no small measure to the outstanding success of the Institute's publications. In his place, Dr E. B. Evans was unanimously elected Honorary Editor and Chairman of the Publications Committee. Dr E. B. Evans, members will recall, has long been associated with the Institute's publications and has for some years been Chairman of the Papers Sub-Committee.

It was unanimously agreed that the progress of the Economics and Operations Group under the guidance of Mr O. Thompson had surpassed all expectations and that the interest shown, as indicated by the attendances at the three meetings of the Group, had been most gratifying. In view of the success of this group, consideration is to be given to the formation of others where the need appears to be the greatest.

Finally, it is to be noted that the Institute's assistance and interest in the permanent petroleum exhibition at the Science Museum has been well maintained and it is expected that finalized plans for the exhibition will very shortly be put forward for approval.

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## PETROLEUM IN PARLIAMENT

### Duty on Hydrocarbon Oils

If the duty on hydrocarbon oils and petrols were reduced by 6d a gallon the cost to the Customs and Excise would be £8 million p.a. in the case of heavy oils used as fuel in diesel-engined road vehicles, and £42 million p.a. for petrol and other light hydrocarbon oils.

This information was given in the House by Mr Boyd-Carpenter in answer to a pre-Budget question.

### Fuel Consumption in the Steel Industry

The following figures, showing the tonnage of coal and oil used in the steel industry, apart from the coke ovens, in the years 1951-3, were given in answer to a recent question.

| *Year* | *Coal* | *Oil* |
|---|---|---|
| | *Thousand Tons* | |
| 1951 | 7343 | 1017 |
| 1952 | 7102 | 1124 |
| 1953 | 6597 | 1328 |

### Natural Gas

In answer to a question about progress in the search for natural gas in the U.K., Mr Geoffrey Lloyd said that an area totalling approximately 3680 square miles in various parts of England and Scotland had been chosen for prospecting purposes. Geophysical surveys were being carried out in Yorkshire and Lincolnshire, a deep borehole was being drilled in Scotland, and it was hoped to start deep drilling in Sussex soon.

Mr Lloyd confirmed that the gas industry was pursuing this research with vigour, and said that it deserved credit for starting up the work in association with the D'Arcy Exploration Co.

### Expansion of British Refining

The cost of the expansion of oil refining in Britain from pre-war to its present level was recently estimated by Mr Joynson Hicks to be approximately £190 million.

### Comparative Increases in Coal and Oil Prices

In answer to a question, Mr Geoffrey Lloyd stated recently that since the beginning of 1946 the pithead price of coal for inland disposal had increased by about 53 per cent and the delivered price of heavy fuel oil by about 32 per cent.

# Chemical Engineering

PART XI—INSTRUMENTATION

*By* **D. C. FRESHWATER**

In all the unit operations discussed in this series emphasis has been placed on continuous processes. These have now replaced almost entirely the batchwise method of operation as practised in the early days of petroleum refining. This is due to the ability to produce products of constant characteristics at a lower operating cost which is a characteristic of continuous processing. However, it is no exaggeration to say that without the invention and development of successful instrumentation to measure, record, and control the main process variables, large scale continuous operation would not have been possible. An appreciation of the mode of operation and the possibilities and applications of industrial instruments and controllers is therefore an essential part of the study of chemical engineers.

The three main process variables which are most often measured and controlled are pressure, temperature, and flow of material. In addition, it is not uncommon to find instruments applied to measure and control liquid level, *p*H, density of mixtures, and many other physical or physico-chemical effects which may have a significant relationship to the correct operation of particular processes.

The chemical engineer should have a working knowledge of the more common methods of measurement and typical control actions, but it must be remembered that much of this field is the province of the specialist engineer. This article is therefore confined to a consideration of some of the means adopted for measuring the important variables of pressure, temperature, and flow and then deals briefly with the theory and methods of control systems. Finally, a few illustrative examples are given of typical instrumentation application in modern refinery practice.

## Measurement

Temperature and pressure are selected as two of the most important variables because of their physico-chemical significance. Flow measurement and control derives its importance from the continuous nature of refinery processes.

*Temperature.* Although the common laboratory mercury in glass type thermometer is not used on the industrial scale, the effect upon which it depends *i.e.*, the expansion of a liquid when heated, is employed. Industrial thermometers of this type may be steel containers filled with mercury or some other suitable liquid. In practice, it is generally necessary to have that part of the instrument which makes the temperature effect visible (*i.e.*, the indicator) remote from the point of measurement for the sake of convenience. This is easily accomplished by connecting the temperature-sensitive element (in general terms, the detector) to the indicator by a suitable length of capillary tubing also filled with fluid. The expansion of the heated fluid in the detector is transmitted through the capillary tube to the indicator, since fluids are virtually incompressible. In the indicator is a flexible metal diaphragm or a curved hollow tube anchored at one end. The expansion of the fluid causes a mechanical movement in the walls of the diaphragm, or bourdon tube as the case may be, and this is transmitted via a suitable mechanical system to a pointer which moves over a dial, thus indicating the temperature.

A very similar device is the vapour pressure type of thermometer in which the detector bulb is filled with a volatile organic liquid. When heated this boils and exerts a definite vapour pressure at a fixed temperature. The indicator is simply a pressure measuring device of either the diaphragm or bourdon tube type, suitably calibrated to read the corresponding temperature.

An important class of thermometer is that using electrical effects. There are two main types. The thermocouple type makes use of the fact that a temperature difference between two junctions of two dissimilar metals sets up an electrical potential in the circuit. The resistance thermometer depends upon the change in electrical resistance of a metallic conductor with temperature change. Both these effects may be made to actuate indicating and controlling mechanisms.

This covers the more common types of industrial thermometers such as are used on continuous process plants. In general, expansion and vapour pressure types are relatively cheap, and give long periods of service without maintenance. They are not so accurate as electrical thermometers and usually are not satisfactory for temperatures above about 250°C. Electrical methods of temperature measurement are often preferred owing to the greater sensitivity to rapid temperature changes since the mass (and hence heat capacity) of the detector is very small. Another advantage is the fact that the impulse from the detector may be transmitted to a remote indicator or controller along a simple electrical conductor rather than a capillary tube. By a suitable switch box as many as 20 detecting elements may be linked to one indicator, and thus temperatures at many different points in the plant may be observed on one instrument.

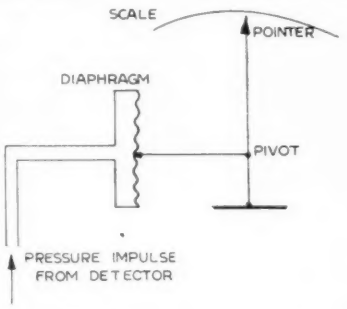


*Fig.* 1. *Diaphragm gauge principle.*

*Pressure.* The simplest method of pressure measurement is by means of a U-tube filled with liquid and connected at one end to the vessel under pressure and open to the atmosphere at the other end. Such a device is suitable only for pressures slightly above atmospheric (up to 1 p.s.i.g. using water, or 10 p.s.i.g. using mercury). Moreover, it cannot be made to actuate a control mechanism conveniently. The commonest type of pressure instrument is the bourdon tube, or the diaphragm type described above in connexion with thermometers and sketched in Fig 1. These may be constructed to measure pressures accurately between 1 inch Hg absolute (*i.e.*, a vacuum of 29 inch Hg) to several hundred p.s.i. Both bourdon and diaphragm types are suitable for use with control mechanisms and can be arranged easily for remote reading. Generally, bourdon tube instruments are used in the higher pressure range, whilst for vacuum gauges the diaphragm type is used. It should be noted that the simple diaphragm gauge shown in Fig 1 measures the difference between atmospheric pressure and the pressure inside the vessel to which it is connected. In vacuum work this may introduce important errors since the change in atmospheric pressure may be appreciable compared with the absolute pressure which is being measured. Thus for accurate work, the diaphragm is enclosed inside a sealed chamber which has been evacuated to a very low absolute pressure. In this way the measurement is not affected by atmospheric changes in either pressure or temperature.

*Flow.* Most industrial flow measuring devices use the principle of Bernoulli's theorem and detect flow by means of measuring pressure difference between two points in the flow system. This was illustrated in the second article in this series on fluid flow. A measurable pressure drop is induced in a flow system by putting some artificial restriction in the line. This may be a venturi tube, as discussed in the article on fluid flow, or more generally an orifice plate (shown in Fig 2). The latter is cheaper and more

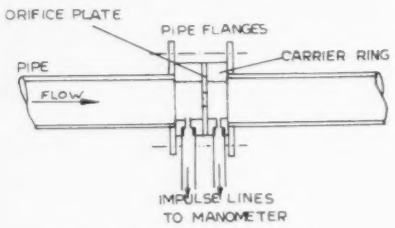


*Fig. 2. Orifice plate assembly.*

simple to install, but has the disadvantage of imposing a permanent energy loss on the system, whereas with a venturi practically all the pressure drop across the restriction is recovered downstream. The pressure drop across these devices is measured by means of a U-tube manometer, described in the previous section.

There are several other types of flow measuring devices based on different principles, but only one of these is used to any extent. This is the rotameter, which comprises a tapered tube inside which there is a solid bobbin free to move along the axis of the tube. The tapered tube, usually made of glass, is mounted vertically with its wide end uppermost, and the fluid introduced into its lower end. The bobbin fits snugly at the bottom of the tube and must be lifted up by the fluid so as to create an annular gap between the bobbin and the tapered wall, through which the fluid can pass. At any steady rate of flow there is an equilibrium position reached by the bobbin where the fluid forces exactly counteract the gravitational forces acting on it. Where the tapered tube is made of glass the position of the bobbin indicates directly the rate of flow. For high pressures, metal tubes are used and the bobbin position is determined by some electrical or electro - magnetic method. A simple diagram of a rotameter is given in Fig 3.

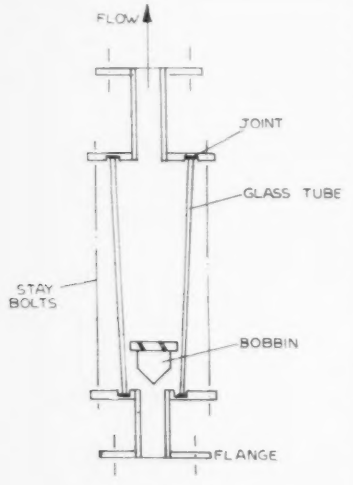


*Fig. 3. Rotameter.*

**The Control of Variables**

So far we have discussed only the means by which the magnitude of important process variables may be measured and changes in these variables detected and indicated. In order that the variable may be controlled it is necessary to combine this measurement and detection with a means of altering the particular variable. In the case of flow control, the impulse from the detector may act on a valve, and open or close it depending upon whether the measured flow is too small or too large. More complex action is necessary in the case of pressure and temperature control but it is not intended to discuss these in detail. In general, whatever the process to be controlled, the control system itself comprises a detecting element or measuring device, a controlling unit, and a regulator. Each of these acts on the one following it and, together with the controlled process, forms a closed loop shown diagramatically in Fig 4. This closed loop idea is the basis of all theory of servo mechanism of which automatic controllers are a small group.

The closed loop will now be considered qualitatively. The detector and the measuring device have already been dealt with. The measuring device, which is actuated by the detector, itself acts upon the controlling unit, and it is this point which will now be described. In effect, the measuring element "tells" the controlling unit how far the variable which it is desired to hold fixed has moved from its proper value. The controlling unit cannot act until it has this information, but when it does it acts upon the regulator, which in turn controls (directly or indirectly) the process variable. This part will be described later but first the controlling unit must be considered. It may be likened to a radio amplifier where a weak signal is increased in strength until it can operate a moving coil speaker. The signal or message from

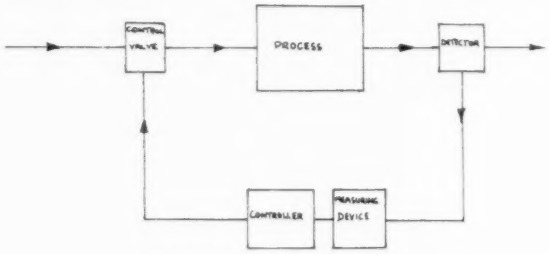


*Fig. 4. Closed loop diagram.*

the detector and measuring device is almost always too weak to be used directly to activate the regulator except in the simplest and crudest devices *e.g.*, a ball float valve where the ball float is the detector and measuring device and acts directly on the valve. Generally, then, the signal must be amplified. Next, the distance of the variable from its desired value must be known by the control unit so that the output to the regulator may be varied accordingly. This is generally a fairly simple matter depending either on direct mechanical linkage between the control unit and the measuring device or on electrical connexion, such that a given movement of the measuring element induces a proportional change in electrical resistance or potential in the controller.

**Regulator Mechanisms**

The regulator must now be discussed. This will almost always be a valve controlling the rate of flow of a process fluid or a service fluid such as steam or water. It is important that the regulator should be neutral with regard to the process variable so that it does not impose its own variation on the closed loop control system. This implies that the same change in output from the control unit always causes the same percentage change in the rate of flow irrespective of the initial flow rate. Consider, for example, the normal gate valve which when manually operated in nearly full open position requires a large degree of gate movement for a small change of flow, whilst at the nearly closed position small changes in valve position give large changes in the flow. This is well-known to the plant operator, who can adjust the valve accordingly, but to use such a valve as the regulator in a control system would make the task of the control unit very difficult if not impossible. Special valves are therefore used in control systems, which give an equal percentage flow change for each unit movement of the stem. Examples of these are the V-port valves commonly referred to in the literature on automatic control.

The simplest type of controller is that in which the valve is either fully open or fully closed. This is known as on-off control and is satisfactory in simple installations, particularly electrical devices, where the time lags in the system between applying the correction and its taking effect are small. It is simple in construction and has the advantage of applying the correction at the maximum possible rate. However, if the time lags in the system are appreciable and if the capacity of the plant is small compared with the demand, then the actual value of the variable will oscillate between extreme high and low values and the method will be useless. This is illustrated by the classic example of domestic hot water usage. A bath, having a large capacity compared with the demand (rate of heat removal), is suitable for on-off control of temperature *i.e.*, the hot tap is opened fully or else shut off. On the other hand, a shower has a very small capacity compared with the demand, and on-off control of the hot water supply to a shower is very unsatisfactory.

The first refinement of this simple system is to make the valve move over a range of values of the process variable. This means that it is half open at the desired value and fully closed at some fixed values above and below this point. This is done by making the output from the controller directly proportional to the deviation of the variable from the desired value and is hence known as proportional control. Thus if P is the controller output, and $\theta$ the deviation from the desired value, then $P = K_2\theta$, where $K_2$ is a proportionality constant. The range over which the valve passes from fully open to fully closed depends on the value of $K_2$ which can be varied by adjusting the control unit. This range is known as the proportional band and is usually expressed as a percentage of the instrument range in terms of the process variable.

Where a small percentage proportional band is used, overall changes in the variables result in large movements of the regulating valve, and, conversely, a large percentage proportional band results in small valve movements for large changes in the process variable *i.e.*, the controller becomes less sensitive. Now, for every value of output or signal from the control unit there is a fixed position for the valve. Suppose the valve to be half open and the process variable at its desired value. If the process load now increases so that the valve has to open, the variable will be held at some value offset from the desired value. The desired value cannot be reached under the new load conditions, because at this value, which fixes the position of the valve, the valve is not open enough to meet the increased load. This offset, or "droop" as it is termed, is a disadvantage of proportional control. The size of the droop is determined by the width of the proportional band and increases as this increases. Most continuous processes have low capacity compared with throughput and also long time lags, and so it is generally desirable to use wide proportional bands. Because of this it is necessary to compensate for the droop, which is large with wide proportional bands, and this may be done manually by altering the supposed value of the desired variable.

It is done most conveniently by building into the control unit a mechanism which automatically resets the control point. This has the effect of superimposing on the proportional output from the controller, a further output which is proportional to the integrated value of the deviation, $\theta$, at any instant. Thus, the

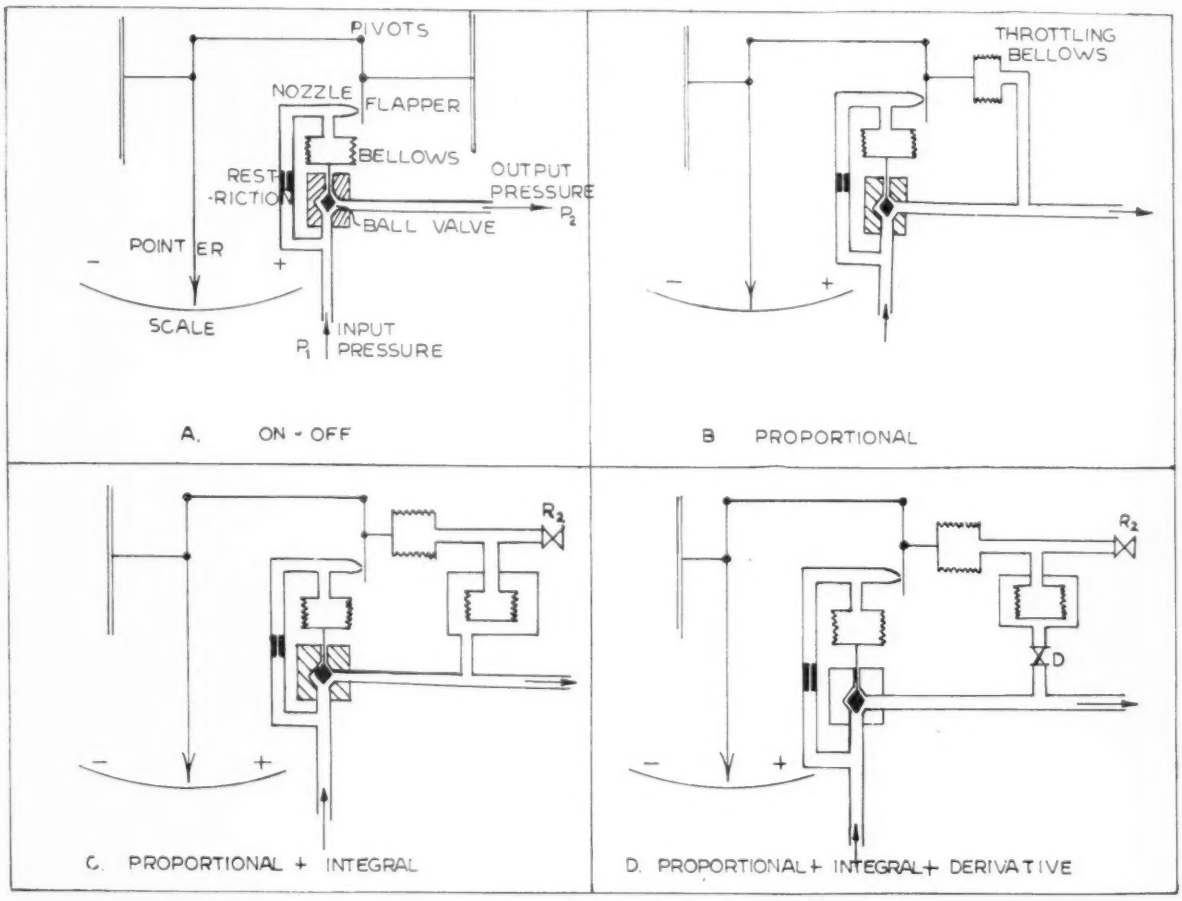


*Fig. 5. Pneumatic control principles.*

longer the variable is different from the desired value, the greater the force being applied to return it. This is known as integral or reset action, and the combination of integral and proportional control is called two-term control.

However, modern industry requires a faster return to the desired value than can be obtained by two-term control and so a third term is added, known as derivative action. In this, an additional output from the control unit is made to depend upon the rate of change of the process variable with time *i.e.*, $P_D = -K_3 d\theta/dt$ where $\theta$ is the deviation from the desired value at time, t, and $K_3$ is a proportionality constant. This means the larger the deviation from the desired value the greater the output of air to $P_2$, *i.e.*, the supply to the control valve or the regulator. This is so installed that the valve moves in a direction to increase the measured variable. Similarly, if the measured variable becomes positive then $P_2$ increases greatly. The change in the position of the flapper through the relay action of the bellows produces so great a change in $P_2$ that this system gives on-off control.

The next mechanism shown in Fig 5b illustrates the basic principles of a pneumatically-powered proportional controller. When a change occurs in the measured variable and the flapper and relay change $P_2$, the throttling bellows act to move the flapper pivot nearer to or further from the nozzle depending on

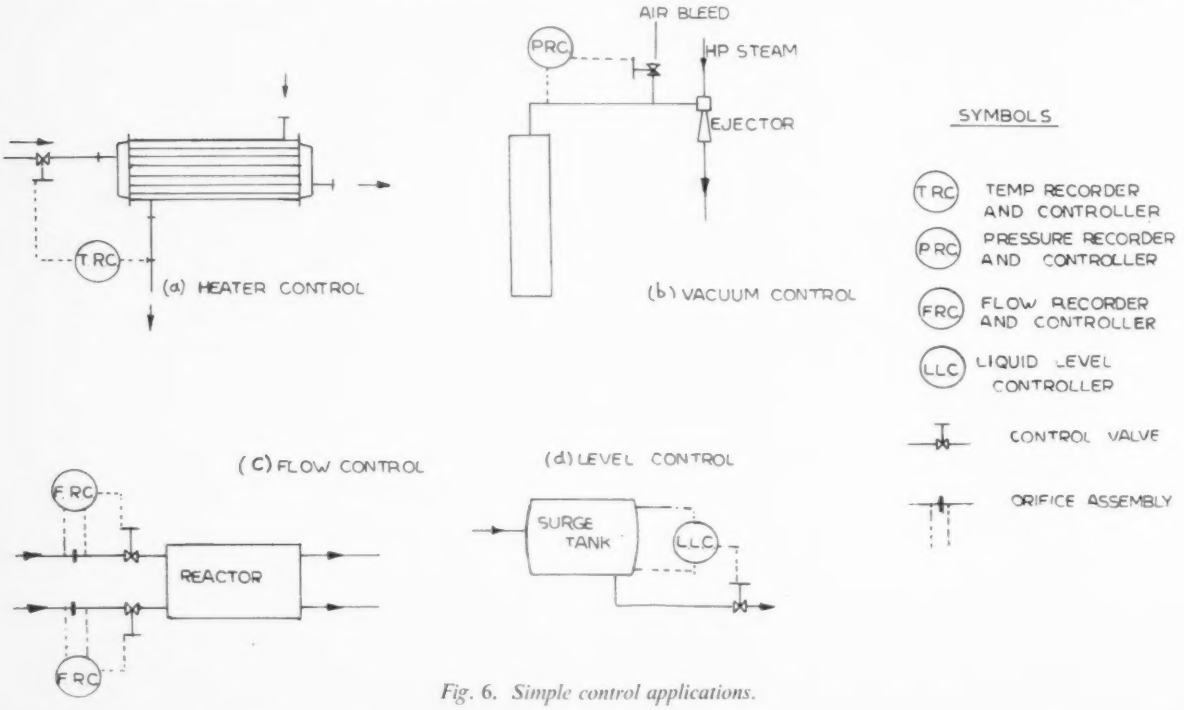


*Fig. 6. Simple control applications.*

being applied to return it, and it has the effect in practice of giving a rapid return to the control setting. It is applied generally to temperature control because in such control systems there are often serious time lags due to the finite time of heat transfer.

Time lags in the closed loop may be of two sorts, those inherent to the process and those included in the control system. The first include such factors as heat or mass transfer lags, demand size capacity, and the distance between the mixing process and the point of measurement. Lags inherent in the control system are beyond the control of the chemical engineer, but it is important that those in the process should be kept as short as possible. This may be done by careful attention to design.

Consider now how these various control actions are achieved in practice. This is illustrated very clearly by the mechanisms used in the most common type of control system where the output from the controller is in the form of air pressure. The regulator is operated by compressed air and the pressure of air is determined by the control unit. On-off action is accomplished by means of the simple mechanism shown diagrammatically in Fig 5a. Air at a constant pressure, P, flows to the ball valve, V, and through the restriction, R, to the nozzle. The flow of air through the nozzle is controlled by the position of the flapper which in turn is positioned by the measured variable. If the variable is negative the flapper is held against the nozzle and the pressure in the bellows is increased. This causes the bellows to expand and close the ball valve, V, thus cutting off the supply which way $P_2$ changes. As explained above, for each position of the measured variable, there is a definite flapper position and a definite output pressure $P_2$. To change the control point the length of the link 1-2 is changed, whilst to alter the width of the proportional band it is necessary to alter the distance between pivots 2 and 3.

By adding an extra set of bellows, $B_3$, and a controlled leak, $R_2$, as shown in Fig 5c, reset or integral action is obtained. The droop or offset inherent in proportional control is overcome by making the proportional action temporary in effect. After a time, which is dependent upon the rate of leak, the flapper returns to its original position. The length of time that this takes is known as the reset time.

In order to obtain derivative action it is necessary only to insert an adjustable restriction, as shown at D in Fig 5d. This slows down the application of proportional and derivative action and makes the controller behave for a short time as an on-off device *i.e.*, any change in the measured variables gives an initial very large change in $P_2$. The effect wears off as the new value of $P_2$ reaches the bellows, $B_3$. The time required for this to happen is known as the derivative time.

Many commercial controllers are available at the present day which incorporate mechanisms to give effect to each of the three terms discussed above, and their successful operation on an industrial scale is a tribute to the skill of the instrument manufacturers.

### The Application of Automatic Control Systems

In the final section of this article some typical applications of automatic control systems in the petroleum industry are discussed. Probably the best examples of their use are to be seen in continuous distillation systems, but first let us become familiar with some basic ideas of automatic control applications with a few simple examples. Fig 6 shows the closed loop system applied

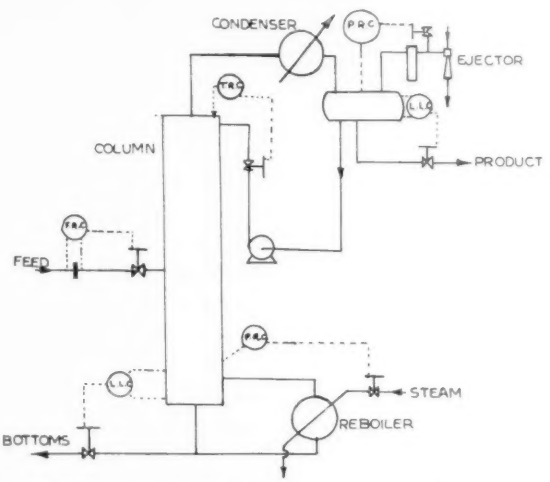


*Fig. 7. Instrumentation of continuous vacuum distillation unit.*

to (a) temperature control on a heat exchange, (b) pressure control on a vacuum system, (c) flow control on a mixing unit, and (d) level control on a surge tank. Conventional symbols used generally to indicate instruments and impulse lines are also shown in this figure. It should be noted that the measuring device and the controller are shown as one unit since this is almost always the case in practice. The way in which the control of the desired variable is achieved is self-explanatory in each of these sketches. The next figure shows each of the above types of control applied to a continuous vacuum distillation unit. This gives some idea of the complexity of the problems of instrumentation.

Only a few of the more important aspects of this subject have been covered in this brief review. A list of references for further reading is given below.


Eckman, D. P., Principles of Industrial Process Control, John Wiley and Sons, Inc., New York, 1945.

Boyd, D. M. *Petrol. Refin.*, 1948, **27** (10), 533.

Isaac, A. H. *Trans. Instn. chem. Engrs.*, 1951, **31** (3), 1.


## CRUDE OIL PRODUCTION

| | *March* 1954 | *Jan.-Mar.* 1954 |
|---|---|---|
| | *Tons* | *Tons* |
| Basrah Petroleum Co. Ltd.—Zubair | 355,732 | 937,927 |
| Iraq Petroleum Co. Ltd.—Kirkuk | 1,916,766 | 5,649,501 |
| Mosul Petroleum Co. Ltd.—Ain Zalah and Butmah | 114,275 | 318,078 |
| Kuwait Oil Co. Ltd. | 4,240,208 | 10,665,861 |
| | *Brl* | *Brl* |
| Kern Oil Co. Ltd.: | | |
| California | 112,760 | 318,654 |
| Trinidad | 82,842 | 244,232 |

## HD OILS

The following additional oils have been approved by the Director of Chemical Inspection, Ministry of Supply, as complying with the requirements of defence specification DEF 2101, Grade OMD 110:—

| *Suppliers' Nomenclature* | *Supplier* |
|---|---|
| Lorco L8220* | London Oil Refining Co. Ltd. |
| Lorco L8230 | ditto |
| Lorco L8250† | ditto |
| Arnoco LHD 20* | James Arnott & Sons Ltd. |
| Arnoco LHD 30 | ditto |
| Arnoco LHD 50† | ditto |
| Arnoco BHD 20* | ditto |
| Arnoco BHD 30 | ditto |
| Arnoco BHD 50† | ditto |
| Pennex HD 30 | United Oil Co. (Stoke-on-Trent) Ltd. |
| Pennex HD 50† | ditto |
| Mancol 30 HD | Marine and Industrial Lubricants Ltd. |
| Caroylak OMD–110 | J. S. Ackroyd & Webb Ltd. |
| Sprillo L 430 | T. R. Parry & Co. Ltd. |
| Batoyle XOD–30 | D. Battye & Son Ltd. |
| Byvolube GL/HD 20* | Alfred Hopps & Sons Co. Ltd. |
| Cyldol Cyldef 30 | H. G. Allcard & Co. Ltd. |
| Silkolene Nectar 10 | Dalton & Co. Ltd. |
| Nerag Motor Oil 800 HD SAE 30 | Gewerkschaft Neue-Erdol Raffinerie |
| Nerag Motor Oil HD SAE 30 | ditto |
| Luberine HD 30 | Forward Lubricants Ltd. |

* Grade OMD 60
† Grade OMD 330

* * *

## AGRICULTURAL RESEARCH

A Shell photo

*At Shell's Agricultural Experimental Station at Woodstock, near Sittingbourne, Kent, research workers are engaged on developing and testing insecticides, fungicides, weed killers, etc. Here, Miss June Streeter is seen estimating tree populations of the fruit red spider mite. Leaves are placed between semi-absorbent paper and mangled, giving impressions which remain for several months without fading, and providing records which can be used for autumn and winter assessments.*

# Around the Branches

FAWLEY, LONDON, NORTHERN, PERSIAN GULF, SCOTTISH, SOUTH EASTERN, SOUTH WALES, STANLOW, TRINIDAD

### Northern Branch

On 16 March G. B. Frost, A.R.I.C., chief chemist of the Watford Chemical Co. Ltd., London, gave a lecture to a joint meeting of members of the Institute of Petroleum and the British Lubricating Oil and Grease Research Organization.

Mr Frost gave a very full and interesting talk on the uses and potentialities of a wide range of surface active agents and indicated their interest to many industries, apart from those represented at the meeting.

He explained that fundamentally there were two possible functions of surface active agents in the preparation of emulsions: the lowering of interfacial tension at the interfaces between the dispersed globules and the continuous phase; and the formation of protective interfacial films.

The first effect made the initial process of mechanical phase subdivision easier and reduced the thermodynamic instability of the system; the second produced a stabilizing action which tended to increase the action produced by lowered interfacial tension, by reducing coalescence. Highly hydrophilic substances tended to promote oil–water emulsions, whereas lipophilic materials produce water–oil emulsions.

The speaker went on to say that the type of emulsion produced would depend not only upon the emulsifier used but also on the method of emulsification. Generally, the most stable emulsions would be produced where the internal or dispersed phase occupied 40-60 per cent of the composition.

Mr Frost stated that it was very rare for one emulsifying agent to be a complete emulsifier in itself; two or more emulgents were normally used. The reason for this was that to achieve complete emulsification it was necessary to reduce interfacial tension, form a protective interfacial film, and impart the optimum viscosity to the continuous phase. Normally, when using a combination of emulsifiers, the primary emulsifier reduced the surface tension, whereas the secondary emulsifier increased the viscosity of the continuous phase and assisted in the production of a rigid interfacial film.

Mr Frost went on to discuss the emulsifying agents in greater detail, classifying them as: anionic agents; cationic agents; nonionic agents; and finely dispersed solids.

Mention was made of various materials available under each heading and the anionic agents discussed were alkali and alkaline earth soaps, polyvalent metallic soaps, bile salts, and sulphated and sulphonated oils and alcohols.

The cationic agents under review were the quaternary ammonium compounds and amine salts. It was pointed out that only recently had interest been shown in these materials as emulsifying agents, as previously they had been used in textile processing, dyeing, and as germicidal agents. Cationic agents generally tended to be absorbed more strongly than anionic materials, said Mr Frost, and the hydrophobic groupings were orientated in the majority of cases towards the aqueous medium, this effect having been used in such processes as waterproofing of textiles, pigment particles, etc., and in ore flotation.

Mr Frost said that under the heading of nonionics came a number of emulsifiers, included among which were most of the edible types. There were a number of advantages in these materials:—

(1) They were less affected by concentrations of electrolytes as they did not depend on ionization for the production of a suitable hydrophilic-lipophilic balance.
(2) They included most of the emulsifiers which could be classed as "edible".
(3) The variation in H-L balance could be achieved more readily and in smaller steps since the solubilizing effect of each non-ionizing polar group was smaller than ionogenic groups.
(4) They were normally compatible with anionic and cationic emulsifiers.

In addition, many were in approximately the same price range as the cheaper anionic and cationic agents. The type of materials under discussion here were, for example, G.M.S., Sorbitan esters, polyglycerol esters, polyglycol, and pentaerythritol esters.

Mr Frost also discussed the materials under the heading of finely-dispersed solids and particular reference was made to bentonites.

Mr Frost concluded the talk with a reference to mechanical emulsification and gave, also, a number of hints as to why many emulsions break down. He pointed out how very necessary it was for manufacturers, who seek technical assistance in the matter of emulsification, to furnish their suppliers with the fullest possible information regarding the products to be emulsified, the methods to be adopted and so on. Without such information a really helpful answer could not be given.

### South Eastern Branch

At a meeting of the Branch held on 6 April, C. L. Tucker spoke on "The Problems of Industrial Relations". He referred to problems affecting the opportunity to work, the capacity to work, and the will to work.

The first problem invited consideration of the changing age composition of the working force, and the second the development of training skills, particularly the training of supervisors and the changing conception of skill caused by the development of new industries in the U.K. The problems affecting the will to work covered the whole sphere of wage structure and wage negotiations.

Mr Tucker dealt with recent developments in wage negotiations and said that he considered quite impracticable some suggestions which had been made for a "National Wage Policy". He went on to deal with the work of the International Labour Office, Geneva, and the success it had achieved in making social progress more general and more sure by promoting minimum international standards and giving technical assistance to ensure the establishment of humane and just conditions of employment.

Mr Tucker concluded by outlining the work of the ILO Petroleum Committee and some of the recommendations it had made.

A number of questions were asked and there was an interesting discussion.

### Social Evening

A social evening was held by the members of the South Eastern Branch of the Institute of Petroleum on Saturday, 10 April, 1954 at the King's Head Hotel, Rochester. The ladies were present and everyone enjoyed a very pleasant evening.

The Chairman, Noel W. Grey, presented the retiring Secretary, Frank Maliphant and the retiring Treasurer, Arthur Chatting, with Ronson lighters, in appreciation by the members for the strenuous efforts made by these two gentlemen in establishing firmly the South Eastern Branch.

Mr Grey then introduced the new Secretary, John R. Moore of Fisher Governor Co. Ltd., and the new Treasurer, Mr Challis of the Anglo-Iranian Oil Company.

Mr Grey referred to the substantial support given to the Branch by members of local companies, such as Le Grand Sutcliff &

*Members and guests during the social evening held recently by the South Eastern Branch*

Gell, Kent Oil Refinery, Berry Wiggins, Woodfield Hoist, Elliott Brothers and others, all of whom are associated one way or another with the petroleum industry. The Chairman went on to say that the South Eastern Branch of the Institute of Petroleum provided a common meeting ground where men of all ranks could meet and discuss their problems in a friendly atmosphere, while at the same time every endeavour was made to maintain a series of talks and papers by people expert in the various branches of industry.

**Stanlow Branch**

At a meeting held on 17 March at the Grosvenor Hotel, Chester, A. N. Holmes gave a paper entitled "Refinery Operational Programming".

Mr Holmes dealt with the procedure employed in the Shell Group, with special reference to the programming of crude throughput at the Stanlow refinery. The intake, explained Mr Holmes, was about 4 million tons p.a. of Middle East crude, divided in an approximate ratio of 4 : 1 between Kuwait and Qatar. Crude tankage amounted to 175,000 tons at Stanlow and 72,000 at Eastham, representing about a fortnight's turnover.

The complex planning of crude distillation, said Mr Holmes, had to be combined with an appropriate programme of plant maintenance and shut-downs. The distribution of products (75 per cent of which left the refinery by sea) also required careful control; there were, for instance, 10 grades of gasoline, and for all these only 96,000 tons of storage in 24 tanks was available.

Mr Holmes said that planning methods were based on a five-year plan, from which a shorter-term plan for five quarters was prepared. Each quarterly plan was then broken down to a four-week schedule at the refinery. In this way, each of the longer-term plans was open to frequent revision if required.

Discussion following the paper was opened by A. Cluer and a vote of thanks to the speaker was proposed from the Chair.

**Trinidad Branch**

On Saturday, 13 March, members of the Branch visited the Brechin Castle Sugar Factory of Caroni Ltd. Several guests and members' wives attended, bringing the party up to 51.

Brechin Castle is one of the most modern sugar factories in the Commonwealth and is, during the present crop season, grinding some 6000 tons of cane daily.

The visitors were conducted through the factory in groups by members of the staff of Caroni Ltd., and concluded their inspection of the various stages in the manufacture of sugar with a walk around the base of a 10,000-ton mountain of sugar awaiting bulk-shipment to the United Kingdom.

On completion of the tour, appropriate liquid refreshment was provided at the Brechin Castle Club.

The Branch Chairman, Dr A. L. Down, on behalf of the Branch and its guests, thanked the management of Caroni Ltd. and J. Guthrie, factory manager, and members of his staff, for a very interesting and well-conducted tour.

"Distribution of Aviation Fuel" was the title of an extremely interesting talk by H. M. Newton and Major D. Hirst of Shell Leaseholds Distributing Co., Ltd. at the 134th General Meeting held on 2 April at which Dr A. L. Down, Branch Chairman, presided.

Mr Newton outlined the progress of aviation with particular reference to the development of piston- and turbine-type power units, and the fuel, and fuelling, problems attendant on the increased speed and range of modern aircraft.

Development of technique from over-wing to under-wing fuelling and the present transitionary stage from tank-wagon to hydrant systems were reviewed.

Major Hirst described the design and construction of the hydrant system for the distribution of fuel, nearing completion at Piarco Airport, Trinidad. Scheduled to be in service in May, the new system will provide distribution facilities for up to four grades—including turbine fuel.

At the conclusion of the talk the Shell film "From Touchdown to Take-off" was shown.

J. W. Hardy moved a vote of thanks to the speakers.

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## SAMUEL BAXTER PRIZE

The Institution of Naval Architects, which makes an annual award of the Samuel Baxter Prize (or prizes) for the best contribution during the year towards safety and/or efficiency in sea-going vessels, has announced its willingness to consider any meritorious claims put forward by the IP on behalf of applicants.

The work submitted must take the form of a paper, essay, description, or drawing of any new design, invention, process, equipment, or apparatus relating to safety and/or efficiency in sea-going vessels.

Submissions must be in the hands of the secretary of the Institution of Naval Architects by 31 December 1954.

# Personal Notes

**John Martin Caldwell** has been appointed managing director of Scottish Oils Ltd., in succession to Robert Crichton, who retired at the end of March.

Mr Caldwell, with the exception of a period in the Royal Flying Corps in 1918, has been in the oil industry all his life. He received his training at the Heriot-Watt College, where he qualified as a mining engineer and took a special diploma in oil mining. His practical experience was obtained at Pumpherston, Philpstoun, and at collieries in Lanarkshire and Midlothian.

Mr Caldwell was appointed assistant refinery manager at Pumpherston in 1923, and some years later was made assistant to the general mining manager and agent for the Central and Eastern Group of shale mines of Scottish Oils Ltd. In 1946 he was appointed general mining manager and two years later general manager of the Company. He was made a director of Scottish Oils Ltd., in 1952.

Mr Caldwell is a director of the Grangemouth Petroleum Refinery Ltd., and of British Petroleum Chemicals Ltd.

Mr Caldwell has been a member of the Institute of Mining Engineers since 1920, and is a member of the Council. He is also Chairman of the Scottish Branch of the Institute of Petroleum. He was among the first to be made a Fellow of the Heriot-Watt College, is a member of the Association of Mining Electrical and Mechanical Engineers, and a member of the Committee of Management of the Firth of Forth Shipowners' Association.

**B. R Fraser,** has been appointed manager at the Coryton refinery of the Vacuum Oil Co. Ltd. Mr Fraser was formerly assistant refinery manager and has taken up his new position on the resignation of D. M. Glendinning.

As a result of Mr Fraser's promotion three additional appointments have been made by the Company. **J. W. Bartholomew,** who was formerly superintendent of the Operating Division, has been appointed assistant manager (Process); **W. Kohring,** formerly superintendent of the Engineering Division, has been made assistant manager of the division, and **H. T. Fuller,** who has been acting as adviser to the refinery management, has been appointed superintendent of the Operating Division.

**C. Stribling Snodgrass,** F.Inst.Pet., and **J. E. Brantly,** who are geologists and engineers specializing in oil and gas developments, have recently set up joint offices in Suite 707 Washington Building, 15th Street at New York Avenue, N.W., Washington 5, D.C.

**N. E. E. Murch** has been appointed fuel oil manager of the Eastern Division of Shell-Mex and B.P. Ltd.

**E. R. McGonnigle,** manager of labour relations for the construction department of The M. W. Kellogg Company, has been elected to the Executive Committee of the National Constructors Association. The M. W. Kellogg Co., which is a subsidiary of Pullman Incorporated, is one of the twenty contractors comprising the NCA.

Mr McGonnigle, who has been associated with Kellogg's construction department for sixteen years, will serve on the Executive Committee for a term of two years.

*E. C. Masterson, F.Inst.Pet.* (right), *manager of the Oil Department, Kuwait Oil Company, photographed during his recent annual visit to Kuwait.*
*Mr Masterson is President of the Hubara Soccer Club and a keen follower of the game. In this picture he is seen congratulating C. Coventry, manager of the President's XI, on a victory over the Chairman's XI. Mr Masterson presented pewter mugs to the winning side.*

**Kenneth B. Ross,** O.B.E., F.Inst.Pet., has been appointed Director of Production at the Risley, Lancashire, establishment of Department of Atomic Energy's Industrial Group. He was general manager at the Abadan refinery when it was shut-down in 1951 and later joined the firm of Costain-John Brown Ltd.

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## AUSTRALIAN OIL SEARCH

In an article on "1954 Prospects of Australian Mining Industry",* J. A. Dunn, chief mineral economist, Bureau of Mineral Resources, writes under the heading "Petroleum" as follows:—

The finding of oil at Rough Range, North-West Cape, Western Australia, by West-Australian Petroleum Pty. Ltd., was an important mineral event in 1953. During 1954, intensive boring activity will continue, in order to prove the extent of oil occurrences in that region, and the find will no doubt stimulate the search for oil in other areas.

The oil obtained in the first borehole is reported to have high paraffin wax content. Whether other oil strikes in the region will be of a similar nature remains to be seen. A great deal of work will be necessary, not only in drilling but also on treatment processes and plant before economic production is proved to be feasible, and this stage is unlikely to be reached in 1954.

The investment in boring in an area where oil has not previously been found is entirely a gamble. The finding of high-wax oil in the Rough Range borehole greatly reduces the odds in investing further money in exploration in that region. The Australian Government has greatly helped in providing a suitable financial atmosphere for investment in petroleum, for under Section 123A of the Income Tax Assessment Act, income from petroleum mining is not subject to tax until the whole of the capital expenditure has been recouped.

*Chemical Engineering and Mining Review, 11 January 1954.

# Colour Standards

*By* G. J. CHAMBERLIN

## Introduction

So many "conversion" tables between various colour scales have been published from time to time (many of them quite empirical and lacking in solid experimental proof) that a rather serious situation has developed, and a feeling of frustration has arisen in people attempting to use visual colour scales in the petroleum industry, as a number of these so-called "conversions" are mutually antagonistic.

It seems, therefore, an opportune moment to re-state the position with regard to certain colour scales which have been standardized and stated, from their inception, in terms of the Lovibond scale.

The figures quoted here are not conversion tables at all, but clear statements of the various colour steps which were laid down by the originators of the scales at their inception. The sense in which the term "conversion tables" is used by the writer refers to those cases where an attempt has been made to correlate in an empirical manner two colour scales which were not originally designed to bear any relationship to each other. For instance, the Institute of Petroleum published a conversion scale between Saybolt and Lovibond,* which was the result of experimental work carried out by members of the Colour Panel, but these two methods of measuring colour were not originally intended to bear any relationship one to the other.

TABLE I

*Revised Numbering of Redwood Scale*

| *Redwood Scale* | *New IP markings given in February* 1924 |
|---|---|
| 1.0 Water white | 1.0 Water white |
| 1.5 | 1.5 Superfine white |
| 2.0 Superfine white | 2.0 Superfine white |
| 3.0 | 2.25 Prime white |
| 4.0 | 2.5 Prime white |
| 5.0 | 2.75 Prime white |
| 6.0 Prime white | 3.0 Prime white |
| 7.0 | 3.5 Standard white |
| 8.0 Standard white | 4.0 Standard white |

In particular, a re-statement of the historical position with regard to the IP scale appears to be timely, because a number of references in the American technical press have shown that some laboratories in the U.S.A. are still using the numbering assigned to the colour scale originated by Redwood and believe that they are quoting current IP values. In fact, as will be seen from the following information, the numbering is not the same although it is applied to the same colours.

## History of the IP Colour Scale

In 1895, J. W. Lovibond, in conjunction with Sir Boverton Redwood, obtained samples from various sources which were considered to be fairly representative of the following four grades: water white; superfine white; prime white, and standard white. These samples were matched in an 18-in cell with Lovibond glasses, and these designations were used and quoted by Redwood and eventually adopted for general use by the trade.

These four standards subsequently became numbers 1, 2, 6, and 8 in a scale for which The Tintometer Ltd. made nine standards, and this for many years was in general although unofficial use. Early in 1924 the Institution of Petroleum Technologists adopted this colour scale in the following terms: "The Lovibond tintometer adopted for use with this scale and an 18-in cell", but the numbers of the steps were revised as shown in Table I.

TABLE II

*Test IP* 17/52

| *IP Standard Glasses* | *Lovibond Colours* | |
|---|---|---|
| | *Yellow* (510) | *Red* (200) |
| 0.25 Water white | 0.2 | 0.43 |
| 0.5 Water white | 0.81 | 0.44 |
| 0.75 Water white | 1.6 | 0.45 |
| 1.0 Water white | 2.3 | 0.46 |
| 1.25 Superfine white | 3.1 | 0.49 |
| 1.5 Superfine white | 3.9 | 0.53 |
| 1.75 Superfine white | 4.75 | 0.57 |
| 2.0 Superfine white | 5.6 | 0.6 |
| 2.25 Prime white | 10.0 | 0.8 |
| 2.5 Prime white | 15.0 | 1.0 |
| 2.75 Prime white | 20.0 | 1.2 |
| 3.0 Prime white | 26.0 | 1.4 |
| 3.5 Standard white | 31.0 | 1.9 |
| 4.0 Standard white | 36.0 | 2.5 |

In February 1924 The Tintometer Ltd. made a set of standards to the new specification for Robert Redwood, who presented them to the Institution to be kept as their standards. This scale has been re-affirmed in each subsequent edition of the handbook "Standard Methods for Testing Petroleum and its Products", and the Lovibond values are given in Table II.

It will be noted that intermediate steps have been added since 1924, making a total of fourteen.

## The ASTM Scale

The ASTM adopted as a tentative scale in 1923, the scale of colour standards for lubricating oils which had been used for some considerable time previously by the NPA.

TABLE III

*Test ASTM D.*155

| *ASTM Colour Numbers* | *NPA Colour Numbers* | *NPA Names* | *Lovibond Analysis* | | |
|---|---|---|---|---|---|
| | | | *Red* | *Yellow* | *Blue* |
| 1 | 1 | Lily white | 0.12 | 2.4 | — |
| 1½ | 1½ | Cream white | 0.60 | 8.0 | — |
| 2 | 2 | Extra pale | 2.5 | 26.0 | — |
| 2½ | 2½ | Extra lemon pale | 4.6 | 27.0 | — |
| 3 | 3 | Lemon pale | 6.9 | 32.0 | — |
| 3½ | 3½ | Extra orange pale | 9.4 | 45.0 | — |
| 4 | 4 | Orange pale | 14.0 | 50.0 | 0.55 |
| 4½ | 4½ | Pale | 21.0 | 56.0 | 0.55 |
| 5 | 5 | Light red | 35.0 | 93.0 | — |
| 6 | 6 | Dark red | 60.0 | 60.0 | 0.55 |
| 7 | 7 | Claret red | 60.0 | 106.0 | 1.8 |
| 8 | 8 | — | 166.0 | 64.0 | — |

These oils are measured in a 33 mm depth

**J. Inst. Pet.*, 1943, **29**, 357.

Originally, there were two tests using this scale in the ASTM series: D.155—for testing the colour of lubricating oils, and D.218—for testing the colour of petrolatum, but both are now combined in the designation D.155. The colours are specified as shown in Table III.

This same scale has been adopted by many countries in Europe and in South America for their own lubricating oil scale.

**Other Specifications in Connexion with Petroleum Products**

The Indian Government has issued its own specification for the colour of lubricating oils, and this is quite a widely quoted scale. The published figures are shown in Table IV.

TABLE IV

*Indian Colour Scale*

| *No.* | *Lovibond Analysis* | | |
|---|---|---|---|
| | *Red* | *Yellow* | *Blue* |
| 1 | 0.10 | 1.35 | — |
| 2 | 1.2 | 14.0 | — |
| 3 | 3.3 | 39.0 | — |
| 4 | 10.0 | 41.0 | — |
| 5 | 11.5 | 51.0 | 0.06 |
| 6 | 21.0 | 50.0 | — |
| 7 | 51.0 | 79.0 | — |
| 8 | 155.0 | 149.0 | — |

The Canadian Government Purchasing Commission has also issued specifications for petroleum colour in terms of Lovibond.

The Standardization of Tar Products Test Committee in its 1950 edition of "Standard Methods" makes use of Lovibond colours in connexion with the following tests:—

| | |
|---|---|
| Colour of benzole | Test L.B.2 |
| Sulphuric acid wash test | Test L.B.10 |
| Determination of carbon disulphide in benzole | Test L.B.17 |
| Determination of thiophen in benzole | Test L.B.21 |
| The determination of corrosive sulphur in benzole | Test L.B.20 |
| The colour of cresylic acid | Test C.C.13 |
| The determination of sulphur in light oil fractions | Tentative method |

There are also British Standard specifications covering most of these in similar terms.

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## THE VOICE OF THE PAST

**Early Examples of Private Enterprise**

The stratum of pitch in Trinidad is usually 4 ft to 7 ft below the surface, and when cut through the pitch melts and oozes out, so that if a man digs down near his neighbour's lot he is able to collect pitch coming from under his neighbour's land.

The court held that pitch was a material and that one had no right to abstract it from a neighbour by the oozing process. (A Court case in Trinidad 1899.)

**The Crystal Ball (Slightly Clouded)**

I cannot say that I was ever wildly imaginative enough to connect the motor car with military expeditions...Already there is a motor scout. This machine is really a combination of the motor cycle and a maxim gun, which is fixed in front of the rider. In addition to this, what is called a "war motor car" is also in course of construction...Will nations eventually go to war against each other in motor cars on land as they do in battleships on sea?...It would surely be of far more practicable value to perfect the machine for steep gradient climbing for peaceful transport purposes first! (Editorial, *Petroleum Review*, 1899.)

# Books and Films

**NRDC Bulletin**

One of the chief aims of the National Research Development Corporation, which was established under the Development of Inventions Act, 1948, is to secure the development or exploitation of inventions resulting from research financed by public funds.

The Corporation has acquired patent rights in many inventions evolved in Government research laboratories, in university laboratories, and in research association laboratories, etc.

A new step to bring these inventions to the notice of industry is the publication of a quarterly Bulletin containing short notes of inventions recently available, together with a selection from inventions which have been the property of the NRDC for some time. Copies of the relevant patent specification and any additional information will be supplied by the NRDC to anyone who is interested in a particular invention.

Copies of the new Bulletin can be obtained from the offices of the Corporation at 1 Tilney Street, London, W.1.

**The Back of Beyond**

No decision has yet been made with regard to the distribution in the U.K. of *The Back of Beyond*, the Shell Film Unit's documentary film on life in inland Australia. Enquiries on this point should be addressed to the Shell Petroleum Company Limited, Public Relations Department, Victory House, 99-101 Regent, Street, London, W.1. Tel. No. REGent 0531, extension 2.

**Oil for the World**

In this book of 100 pages S. Schackne and N. D'Arcy Drake have provided for the general reader a very readable and well-illustrated introduction to oil. After outlining the importance of petroleum products to modern welfare and economy, there follow chapters on the formation, location, and production of crude petroleum and an account of how that raw material is refined and transformed into usable products. Published by Esso Petroleum Co. Ltd., the price is 12s 6d.

**British Equipment Manufacturers**

The names, addresses, and manufactures of the nearly 400 members of the Council of British Manufacturers of Petroleum Equipment are set out in a new *Classified List of Equipment and Services* just issued by the Council. The equipment available is also listed under numerous subject headings, which itself is separately indexed. Priced at 5s., this publication can be obtained from the Council's offices at 79 Buckingham Palace Road, London, S.W.1.

**PEI Journal**

First published in January 1954, this is the official organ of the Petroleum Educational Institute, and will appear at least six times per year. Its function is to "cover the fundamentals of new and changing developments...which sales and service personnel will find useful in their daily work". Information is also given on matters of general petroleum industry. The first two issues are already available and are profusely illustrated with the type of drawing for which the PEI is noted. Price, including binder, is $15.00 per year (U.S.A. $10.00 and Canada $12.00) and the PEI address is 9020 Melrose Avenue, Los Angeles 46, California.

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## CHANGE OF ADDRESS

The Glasgow office of The Hamworthy Engineering Co. Ltd. and British Combustion Ltd., has changed its address to 163 St Vincent Square, Glasgow, C.2.

# United Kingdom Petroleum Consumption

NEW RECORD IN 1953

Statistics of U.K. oil consumption in 1953 have just been published by the Petroleum Information Bureau on behalf of the U.K. Petroleum Industry Advisory Committee. These show that in 1953 consumption (exclusive of bunkers for ships engaged in foreign trade) totalled 19,002,695 tons compared with 17,510,285 tons in 1952.

One of the largest increases occurred in demand for motor spirit (consumption 5,739,955 tons as against 5,440,552 tons in 1952). This demand was divided between premier grade spirits (consumption 2,452,632 tons) and standard grades (3,287,323 tons). In 1953 premier grade spirits were on sale in the U.K. for the first time since the war. One interesting feature is that although the bulk of premier grade spirits is taken by dealers for supply to private motorists, commercial consumers took 255,378 tons of premier grade compared with 1,709,063 tons of standard grade. Dealers took 2,197,254 tons of premier and 1,578,260 tons of standard.

Other items showing a major increase included gas/diesel and fuel oil—which altogether accounted for 5,532,465 tons (excluding refinery consumption) against 5,098,194 tons in 1952. The mounting consumption of these products reflects increasing industrial activity. The only product for which consumption has declined compared with 1952 is kerosine—partly due to the growing use of diesel-engined tractors. Details extracted from the report are given in Table I.

Table II shows the growing output of home-refined products. Last year, British refineries produced 25,395,959 tons against 22,490,363 tons in 1952. While fuel oil (10,747,120 tons) was the largest single product, the biggest increase occurred in motor and aviation spirit which amounted to 6,243,355 tons (1952 output: 4,935,418 tons). Gas and diesel oil also showed an appreciable increase. Among products supplied from indigenous materials, benzole came to 233,622 tons against 175,493 tons in 1952.

TABLE I

U.K. PETROLEUM CONSUMPTION

| | 1952 *Tons* | 1953 *Tons* |
|---|---|---|
| Motor spirit (incl motor benzole): | | |
| Dealers: Premier grades | — | 2,197,254 |
| Standard grades | 3,492,728 | 1,578,260 |
| Commercial consumers: | | |
| Premier grades | — | 255,378 |
| Standard grades | 1,947,824 | 1,709,063 |
| Industrial spirits (incl. indust. benzole) | 78,854 | 100,917 |
| White spirit | 137,394 | 140,998 |
| Kerosine: | | |
| Burning oil | 577,481 | 546,708 |
| Vaporizing oil | 865,692 | 833,051 |
| Derv fuel | 1,180,440 | 1,270,773 |
| Gas, diesel, and fuel oils: | | |
| Burning | 3,245,208 | 3,550,845 |
| Power | 1,216,867 | 1,330,332 |
| Gas and other manufacture | 506,276 | 502,820 |
| Refinery consumption | 1,256,075 | 1,508,491 |
| Petroleum industry | 129,843 | 148,468 |
| Lubricating oils and greases | 751,961 | 794,238 |
| Paraffin wax and scale | 30,418 | 40,053 |
| Propane and butane | 48,688 | 53,164 |
| Bitumen | 721,936 | 749,526 |
| Other products | 1,322,600 | 1,692,356 |
| TOTAL | 17,510,285 | 19,002,695 |

TABLE II

U.K. PRODUCTION OF PETROLEUM PRODUCTS EX IMPORTED AND INDIGENOUS CRUDE AND PROCESS OILS (INCL. SHALE)

| | 1952 *Tons* | 1953 *Tons* |
|---|---|---|
| Motor and aviation spirit | 4,935,418 | 6,243,355 |
| Industrial spirits | 2,310 | 2,384 |
| White spirit | 53,046 | 45,126 |
| Burning oil | 568,764 | 472,971 |
| Vaporizing oil | 39,277 | 80,334 |
| Gas/diesel oil | 3,865,481 | 4,303,935 |
| Fuel oil | 10,097,836 | 10,747,120 |
| Refinery fuel consumption (ex own production) | 1,240,586 | 1,494,646 |
| Bitumen | 715,080 | 715,887 |
| Paraffin wax, scale, and slack wax | 14,635 | 15,217 |
| Lubricating oil | 369,720 | 365,891 |
| Propane and butane | 24,954 | 48,309 |
| Miscellaneous products and loss | 563,256 | 860,784 |
| TOTAL | 22,490,363 | 25,395,959 |

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## TRADE LITERATURE ETC.

### Aldrin

Further information about Aldrin, a new insecticide manufactured by Shell, is contained in a twenty-page descriptive booklet giving details of the action of Aldrin in the soil, methods of application, and recommended dosage rates.

### Lap-Speed Calculator

A lap-speed calculator has been produced by the Vacuum Oil Co. Ltd. for use at car and motor cycle race meetings. It is based on the slide rule principle and given the length of a lap and the lap time, the lap speed can be read off at once.

The calculator is to be distributed at motor and motor cycle race meetings and through motor cycle dealers and clubs.

### New Welding Research Laboratories

The Quasi-Arc Co. Ltd., manufacturers of electrodes and equipment for arc welding, have recently extended their premises with the completion of a new block of research and development laboratories. A special opening ceremony was held and the laboratories were opened officially by J. S. Hutchison, chairman of the British Oxygen Group of Companies.

The new block is concerned particularly with electrodes, research and development on welding equipment being carried out in separate laboratories. Eight main laboratories make up the building in which the following branches of research will be undertaken: electrode development; chemical analysis; spectrographic analysis; mechanical testing; physical testing; metallography and petrology, X-ray diffraction, and industrial radiography.

### Posted Price for Seria Crude Oil

Sarawak Oilfields Ltd., a member of the Royal Dutch/Shell Group of oil companies, has announced that it is to post its export price f.o.b. Lutong for cargoes of light Seria crude oil of 37°/38° API gravity. The price effective from 1 April 1954 until further notice is to be U.S. $2.60 per brl of 42 U.S. gallons.

Copies of the company's official posting schedule can be obtained direct from the registered office of Sarawak Oilfields Ltd., Miri, Sarawak or through The Anglo-Saxon Petroleum Co. Ltd., London.

# Notes of the Month

### New Butane Sphere at Stanlow

Difficulties arose at the Shell refinery, Stanlow, recently, when a new welded steel sphere, 35 ft in diameter, had to be coupled up with existing spheres used for the storage of butane.

Welding could not be carried out near these vessels and so the sphere had to be erected and welded on a temporary foundation 120 ft from its final position. A 150-ton boom derrick was used to lift the sphere, the size of a house and weighing 70 tons, into the air and swing it into position. The sphere was then bolted down on its permanent foundations.

### BP Expansion in Morocco

Since Anglo-Iranian's BP products first became available to motorists in Morocco last year, rapid progress has been made in the building of a chain of BP service stations throughout the country.

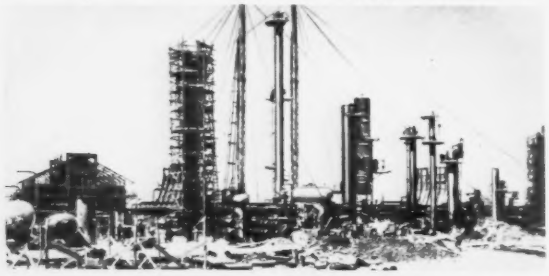
Distribution of these products is handled by Anglo-Iranian's North African associate, Société des Huiles de Pétrole BP du Maroc.

The first BP service station was opened last May on the Mazagan-Casablanca road. There are now nine such stations in operation, six on the main highways in Morocco and the remainder in the towns of Meknes, Fez, and Fkih ben Salah.

A further programme is in hand to expand the network of BP service stations throughout the main centres of Morocco.

### Chile's First Oil Refinery

The first Chilean oil refinery, which is under construction near Valparaiso, is expected to be completed late this summer. The refinery has been designed and equipped by the M. W.



Kellogg Co. for Empresa Nacional del Petroleo, and construction is under the supervision of the Kellogg Pan American Corporation.

The refinery will have a capacity of 20,000 b.d. and will process both native and imported crudes. Products will include, in addition to liquid petroleum gas, motor gasoline, tractor gasoline, kerosine, two grades of diesel oil, and heavy fuel oil.

### Expansion of Oil Facilities in West Africa

New oil storage facilities are now being constructed in West Africa as part of a £2 million programme to improve oil supply service to shipping and inland consumers.

The scheme has been initiated by Shell and provides for new bunkering facilities at Dakar as well as a large ocean installation at Apapa. The bunkering installation at Dakar is being constructed on ten acres of land reclaimed from the sea. Four tanks, each capable of holding nearly 15,000 tons of fuel and diesel oil, will be built this year, and two more of the same size are scheduled for future construction.

In addition, three bitumen tanks are to be built for inland distribution. These will have a total capacity of nearly 9000 tons.

At Apapa, fourteen storage tanks are being constructed on 35 acres of land which is being reclaimed from swamp. This project, which is scheduled for completion this year, is the main part of a plan to expand distribution facilities in Nigeria.

### Oil Group Exports

During 1953, stores and equipment totalling £29 million in value were exported from the U.K. by the Royal Dutch/Shell group of oil companies. In addition, several millions of pounds were spent in the U.K. on new refinery plant, on tankers and materials for the Shell fleet, and the maintenance of existing facilities and vessels.

Exports covered a wide variety of materials and deliveries were made to almost every country in the world.

A Shell photo

*Photographic students from the Warrington School of Art recently made an evening tour of the Shell refinery at Stanlow in order to practise industrial photography at night. The varied light and shade in the complex structures of the refinery provided excellent scope for the students to exercise their skill.*

*Flash photography was, of course, prohibited for reasons of safety but the "cat cracker" and the huge spherical storage tanks for liquefied gas proved particularly photogenic.*

*Photo shows members of the party photographing the "cat cracker" at Stanlow.*

### Petrol Used as Ballast in Bathyscaphe Descent

Specially-prepared petrol was used as light ballast in the bathyscaphe FNRS III, which was taken down to the world record depth of over 2½ miles off the coast of Dakar early this year.

Two kinds of ballast were required to allow the bathyscaphe to raise and lower itself when submerged; heavier-than-sea-water and lighter-than-sea-water ballasts. The first was provided in the form of granulated iron, and it was found that a light petrol satisfied the second need for a light ballast which was not easily compressible but was sufficiently light to give buoyancy.

The ballast was contained in a tank separate from the special observation sphere, and the release of both the granulated iron and the petrol was controlled by electro-magnets.

The light petrol was obtained by the distillation of Middle East crude in the new Shell-Berre topping unit at Berre l'Etang, near Marseilles. Distillation range of the fraction was between 40° and 125° C and the vapour pressure was 9 p.s.i. The specific gravity at 15° was 0.678. The results of compression tests were charted to determine the specific gravity at various depths in order to calculate the increasing depth of the bathyscaphe and to control its descent.

### New Range of Vehicles for Shell Oilfields

A new type of vehicle, the six-wheeled, six-wheel drive "Constructor", has been ordered by the Shell Petroleum Co. Ltd.,

A Shell photo

*Three-quarter rear view of the Scammell 6 × 6 "Constructor" chassis.*

for use in the oilfields of Venezuela, Colombia, Seria (British Borneo), and Indonesia.

The "Constructor" is supplied by Scammell Lorries Ltd., and the chassis will operate in the oilfields with different wheel-bases to suit several types of body work and equipment. Shell's total order is for 38 vehicles including tractors for operation with heavy-duty semi-trailers, trucks for carrying very large unitized loads, chassis mounted with the latest well-servicing hoists, and different types of crane units.

The vehicles are powered with the Rolls Royce C6.NFL six-cylinder diesel engine or, for less arduous conditions, the Meadows 6 DC-630 six-cylinder diesel engine.

### ACW Group to Market Vacuum Oil

Fuel oils produced at the Coryton refinery of the Vacuum Oil Co. Ltd. are to be sold on the South coast by Associated Coal and Wharf Companies Ltd.

This joint arrangement follows the Vacuum Oil Company's policy of appointing established fuel merchants as its fuel oil marketers. Vacuum's first partnership of this kind was with Charrington, Gardner, Locket (London) Ltd. in the London and Home Counties area.

### Record Shipment of Steel Pipes

Steel pipes weighing 8400 tons were shipped from Glasgow recently for Haines in Alaska. The shipment is believed to be a record for steel pipes loaded on one ship, and represents half of

*Loading the steel pipes at King George V dock, Glasgow.*

a million pound order which is being fulfilled by Stewarts and Lloyds Ltd.

The pipes are to be used in the construction of the Haines-Fairbanks pipeline to convey fuel for U.S. aircraft.

### Corrosion Congress in Germany

The Working Party on Corrosion is to organize a Corrosion Congress in Frankfurt (Main) on 11 and 12 November this year.

The Working Party, which is made up of representatives of German scientific and technical societies, last met as an international body in 1943.

### New Refinery for Canadian Petrofina Ltd.

Work has begun on a 20,000 b.d. refinery which is to be built near Montreal for Canadian Petrofina Ltd. The designing of the major part of the processing units is being carried out by the M. W. Kellogg Co., and the Canadian Kellogg Co. Ltd. is to erect the units and all off-site facilities.

Much of the new plant is to be of integrated combination design, and it is hoped that the project will be completed in the latter half of 1955.

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A Shell photo

*Ninety-five retired tanker masters and chief engineers met at the Grosvenor Hotel, London, recently for the fifth annual reunion and dinner of the Shell Fleet Retired Staff Association. The total service of those attending amounted to over 2500 years.*

# Progress at Aden and Kwinana

Construction work on the new refineries at Aden and Kwinana which are being built for the Anglo-Iranian Oil Co. and its associate Australasian Petroleum Refinery Ltd., respectively, is progressing rapidly. It is hoped that the Aden refinery will be commissioned this year and Kwinana early in 1955.

Engineering and drafting for the Aden refinery is now virtually complete, and about 90 per cent of the materials needed for the refinery plant have been despatched to the site. Since work officially began in November, 1952, approximately 165,000 tons of material and equipment have been shipped to Aden, mainly from the U.K. and Europe. Of this, 100,000 tons have been for permanent works in the refinery and port.

Work has begun on the erection of all the refining units, and the $SO_2$ unit, designed to treat 8000 barrels of kerosine a day, is almost complete. The two crude units, which will each have a throughput of 60,000 barrels of Middle East crude a day, are 65 per cent overall complete.

Prefabrication has greatly speeded the erection of the main towers on the site, for each tower has been shipped from France in three sections ready to be lifted into place. Time has also been saved in the construction of storage tanks at the refinery.

The second of three 7500 KW turbo-alternators has been installed at the refinery power station, and six pumps, each with a capacity of 1,000,000 gallons an hour, have been set up in the salt water pumphouse.

Work on the port, which will accommodate four 32,000-ton tankers at one time, is also up to schedule. Vast quantities of rock have been quarried from nearby hills and tipped on permanent harbour works which include a 9000-ft bund and a 4000-ft breakwater. Sand secured by dredgers deepening the harbour and approach channel is being pumped inside the bund and 200 acres will eventually be reclaimed.

At Kwinana also, work has begun on the erection of all the refining units. 70,000 tons of materials and equipment have already arrived, leaving only a further 30,000 tons to complete the estimated requirements for the whole project. Most of the material for the refining plants has come from the U.K. and America, but a large proportion of steel plate for tankage, steel piping, etc., has been purchased in Australia.

The two distillation units and the vacuum unit are each about one-third complete, and work is well advanced on the catalytic cracking unit.

Prefabrication has been used in Kwinana also in the construction of a 127-ft fractionating tower for one of the distillation units which was brought in four sections from America.

An Anglo-Iranian photo

*An aerial view of the Aden oil refinery seen from the South.*

An Anglo-Iranian photo

*Final welding of the main fractionating tower of a 35,000 b.d. distillation unit before it was lifted into the vertical position at the Kwinana oil refinery.*

Work on the refinery jetty which is being built out into Cockburn Sound is about one-third complete, and nearly 4,000,000 cubic yards of sand have already been dredged from the two banks at the entrance to the Sound.

Housing for permanent staff and labour is a problem which is also being tackled at both refineries. At Kwinana over 300 of the 1000 houses being built by the Western Australian Government at Medina, one of four new housing estates near the refinery, have been taken over by the Company.

* * *


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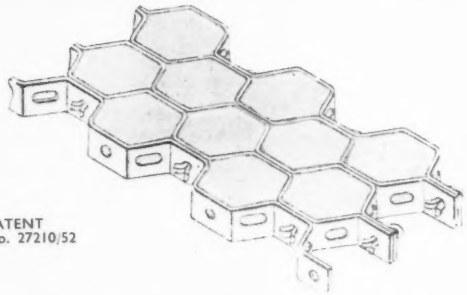

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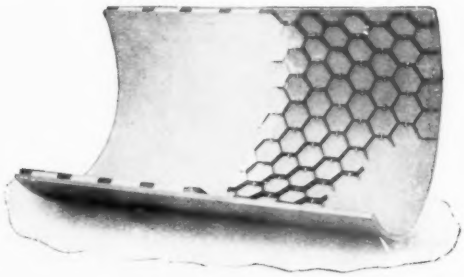

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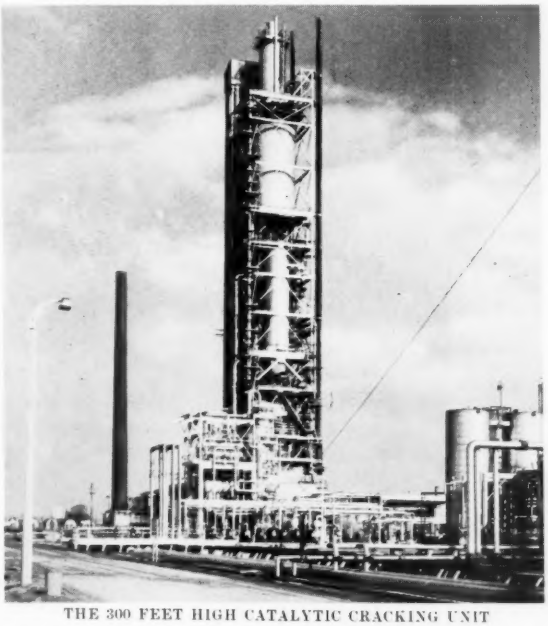

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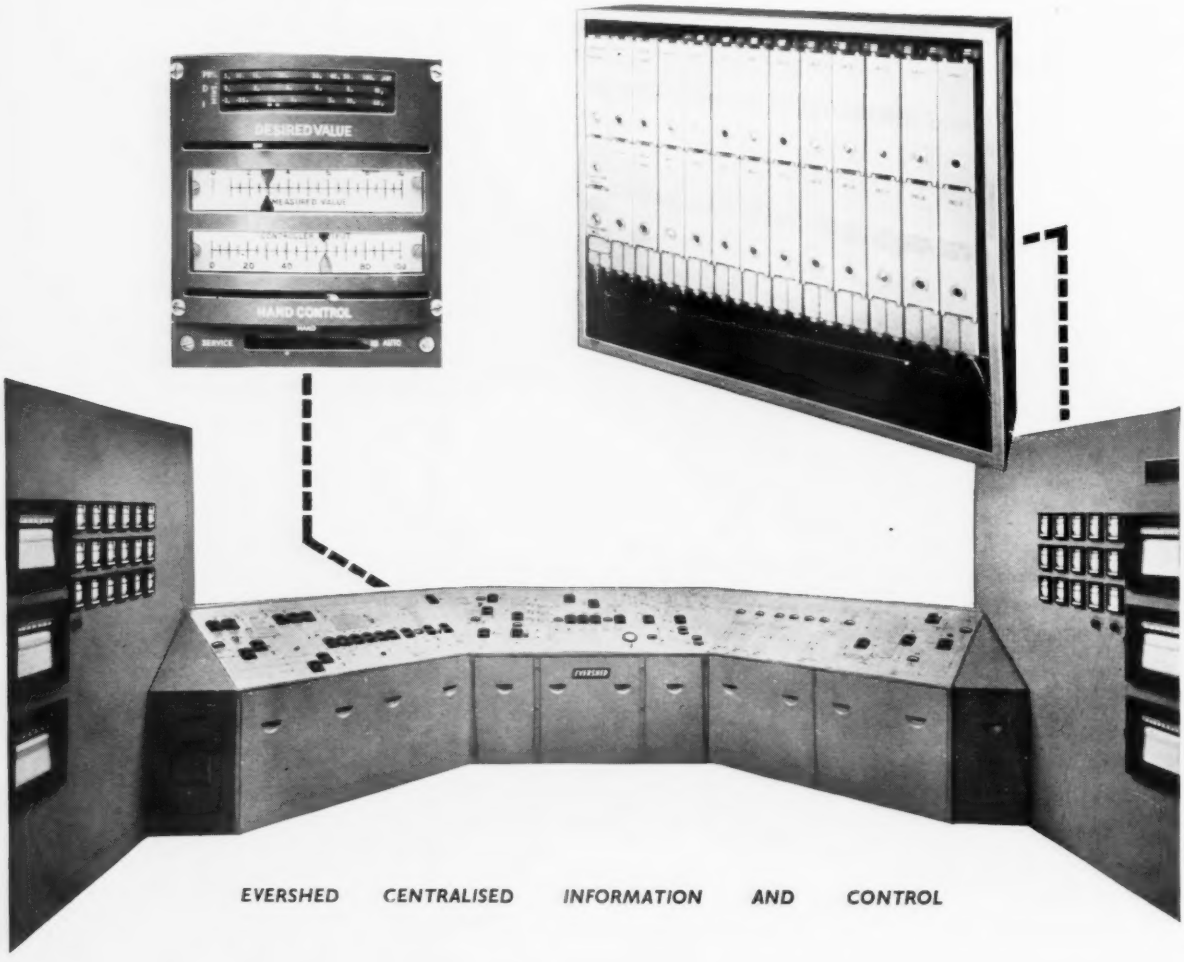


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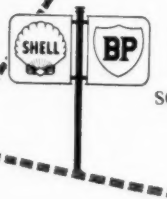

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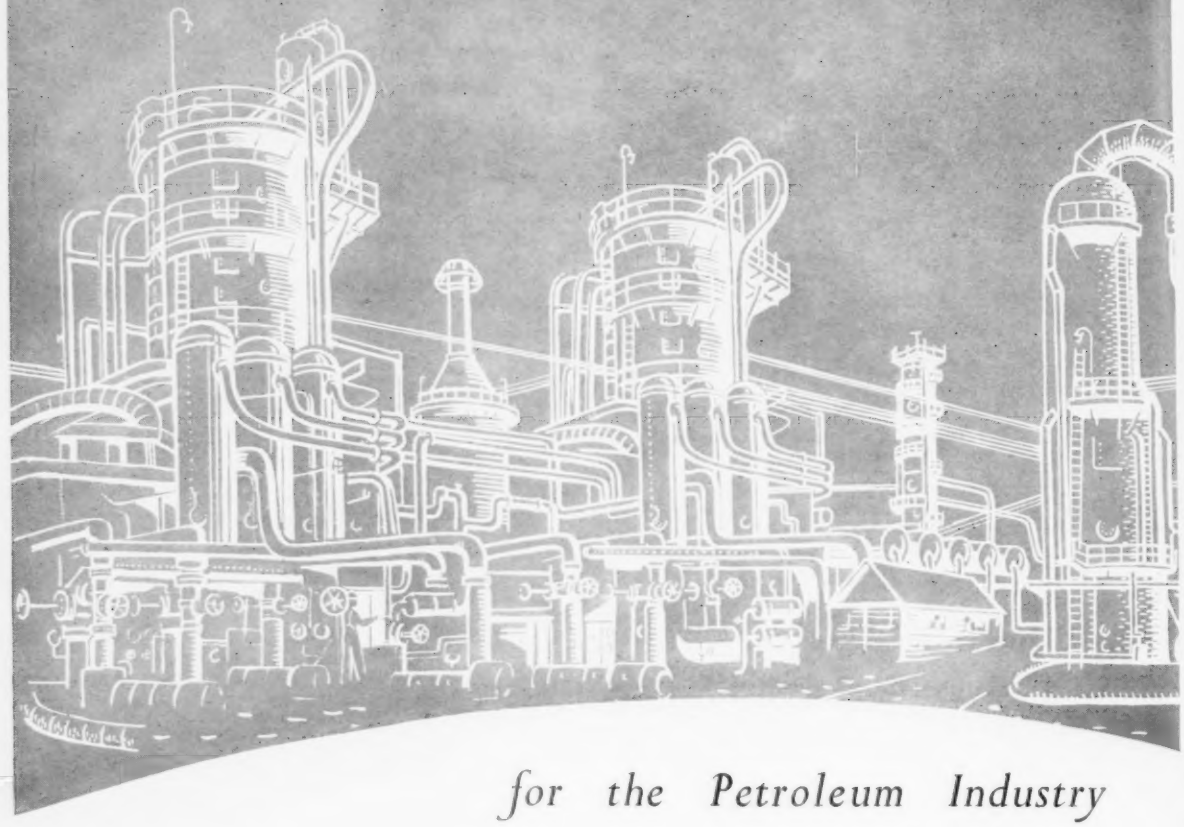

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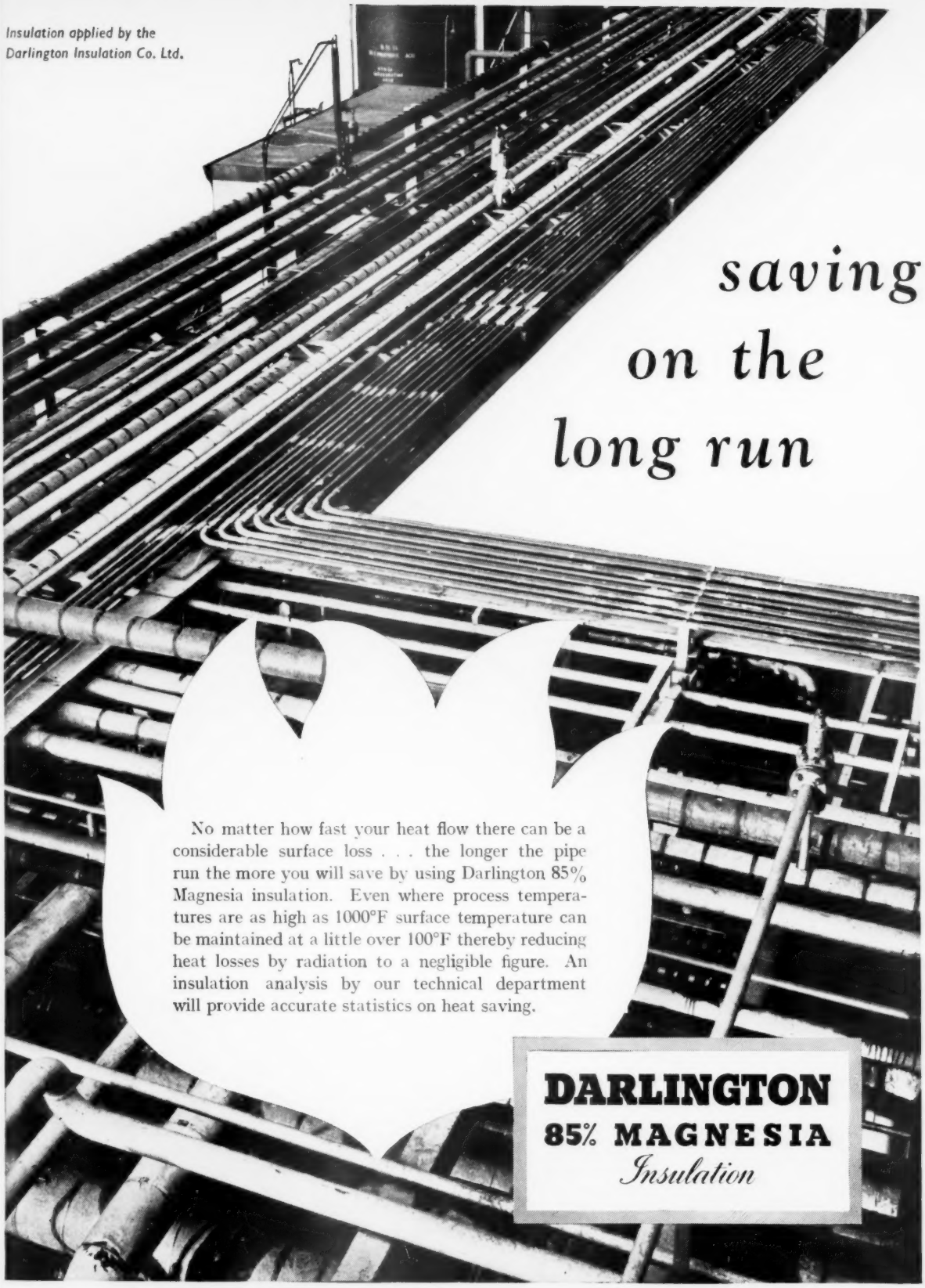

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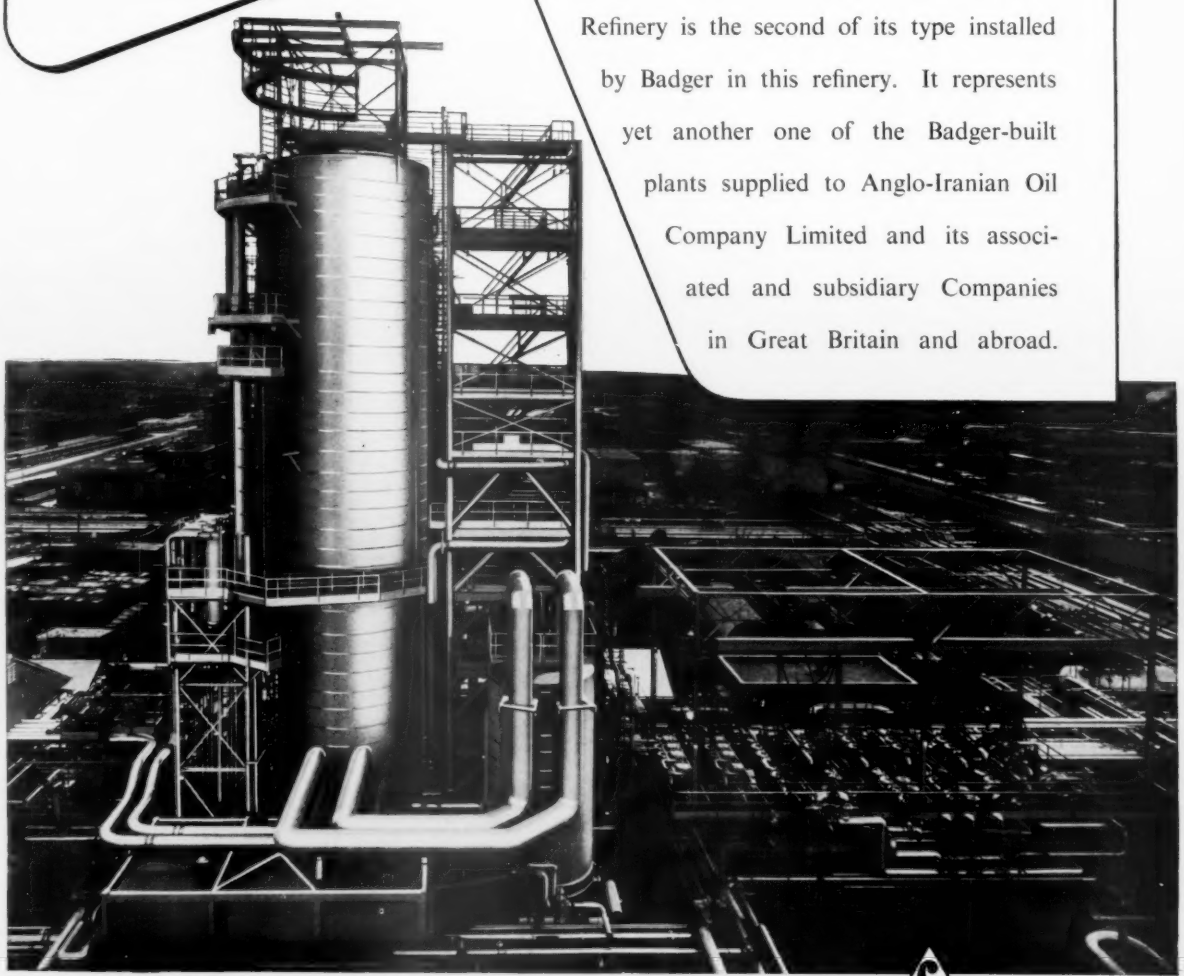

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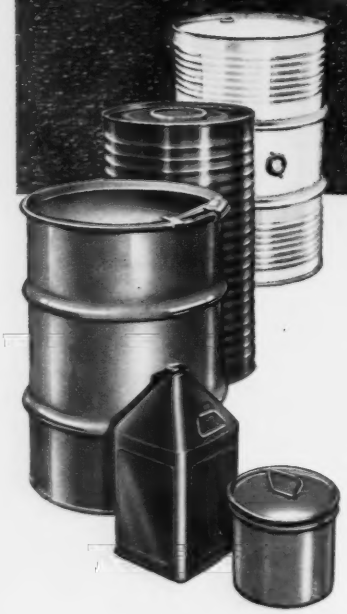

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